BENTHIC DIVERSITY IN SOME DERELICT WATERBODIES OF ALIGARH

THESIS

SUBMITTED FOR THE AWARD OF THE DEGREE OF

Doctor of Philosophy

IN

ZOOLOGY

BY

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UNDER THE SUPERVISION OF

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SECTION OF FISHERY SCIENCE & AQUACULTURE
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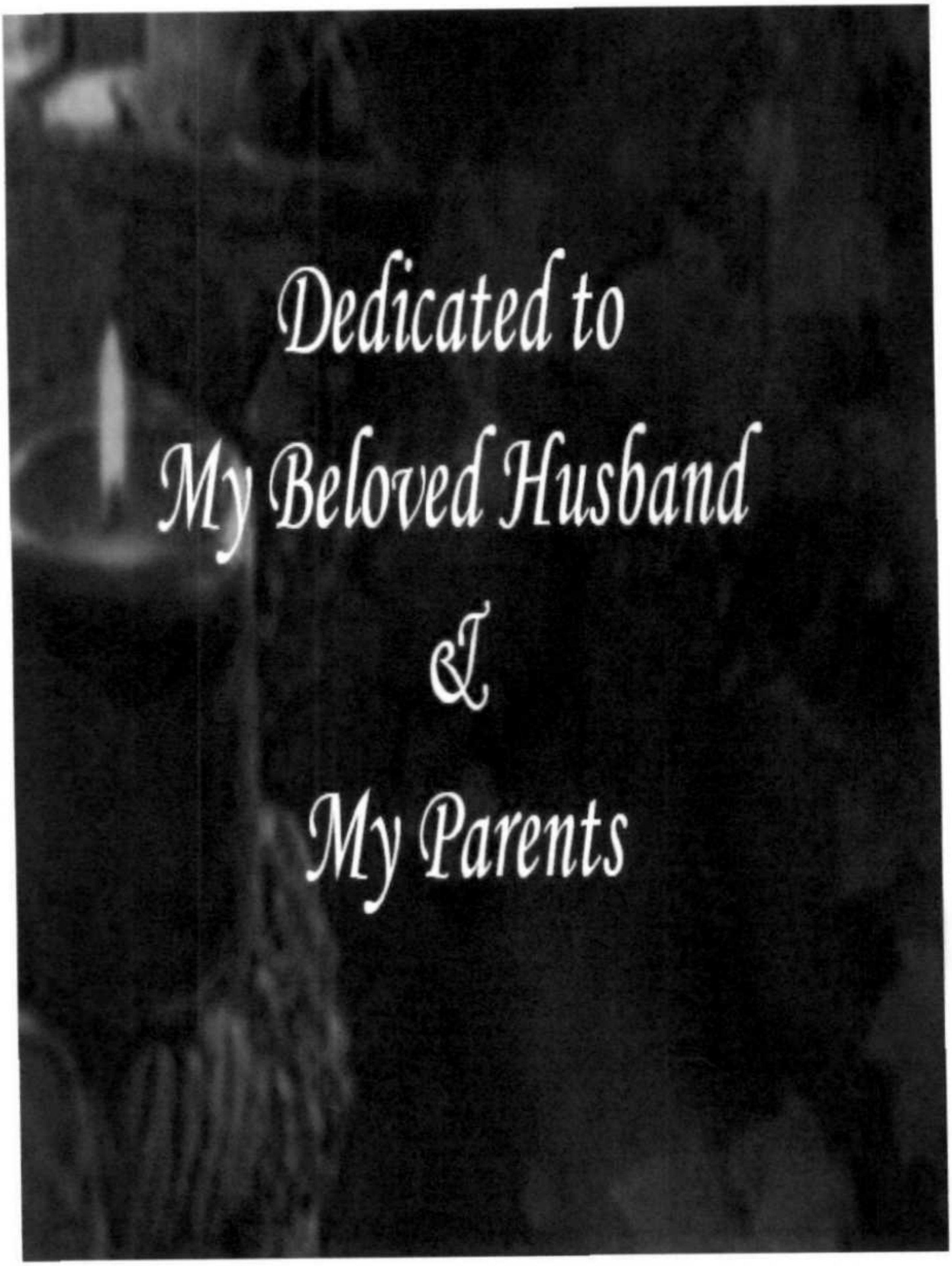
Dedicated to
My Beloved Husband
&
My Parents

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DEPARTMENT OF ZOOLOGY
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ctions :
1. ENTOMOLOGY
2. FISHERY SCIENCE & AQUACULTURE
3. GENETICS
4. NEMATOLOGY
5. PARASITOLOGY

D. No. ..../ *ZD* ....

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CERTIFICATE

This is to certify that the work presented in this thesis entitled, **"Benthic diversity in some derelict waterbodies of Aligarh"**, by **Mrs. Habeeba Ahmad Kabir** incorporates the results of her independent study carried out under my supervision. I consider it a good piece of work with a considerable amount of addition in existing knowledge on benthic faunal diversity of lentic waterbodies of India. She is therefore, allowed to submit this thesis for the award of **Ph.D.** degree in Zoology of **Aligarh Muslim University, Aligarh.**

Saltanat

Dr. (Mrs.) Saltanat Parveen

(Supervisor)

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Proclaim! And thy lord is most bountiful
He who taught the use of pen
Taught man that which he knew not!
(Surah Alaq: 3-5, Al-Quran)

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Chapter I

Introduction $ Review of Literature

INTRODUCTION AND REVIEW OF LITERATURE

Water is the mother of life and it is the most precious gift of the nature. About 71 percent of earth's surface is covered with water 97.3 percent of global water exists in ocean and remaining 2.7 percent in glaciers, lakes, rivers and wetlands. The total surface area of lakes accounts to roughly 1.8 percent of the land area, or about 2.5 million km^2, the volume of water contained in them is 2.80×10^3 (Schwoerbel, 1987).

Due to unique hydrological properties, the aquatic ecosystem has supported the development of a very complex biotic community on the earth. Virtually every form, composition, altitude and latitude are populated with organisms both plant and animal, although the composition differs greatly with differences in the various waters. With few exceptions, all the major groups of plants and animals are represented, often by a great array of species. Aquatic ecosystem is thus important sustainers of biodiversity which encompasses freshwater ecosystems, including lakes, ponds and reservoirs, rivers and streams, groundwater and wetlands. Aquatic biodiversity has enormous economic and aesthetic value and is largely responsible for maintaining and supporting overall environmental health. Human has long depended on aquatic resources for food, medicines and materials as well as for recreational and commercial purposes. Other organisms also rely upon the great diversity of aquatic habitats and resources for food materials and breeding grounds.

The organisms of lake are conveniently grouped ecologically into those associated with the free water, those associated with solid-water interface and those at the surface in film and can undertake swimming movements in any direction in spite of turbulence. Gams (1918) have given systematic classification suitable for all organisms living in aquatic environment. These three assemblages are known as ephaptomenon, rhizomenon and planomenon respectively. As far as aquatic form are concerned, the ephaptomenon, consist of attached plants which were called as Nereid's by Warming (1895) and Haptobenthos by Hutchinson (1967).

However, the organisms associated with solid liquid interface are ordinarily termed as benthos (Haeckel, 1891) and may be divided into phytobenthos and zoobenthos. The term Benthos is derived from two Greek words "*Ben*" meaning 'the collection of organisms living in or on the sea or lakes' and "*Thos*" 'the bottom of sea or lakes'. Hutchinson (1967) defined benthos as an association of species of plants and animals that live in or on the bottom of a body of water.

Their size may vary from 1 micrometer to > 1 milimeter and they are named accordingly:

Microbenthos: Organisms 1-100 micrometer in size e.g. bacteria.

Meiobenthos: Organisms which are 100-1000 micrometer in size

Macrobenthos: Organisms which are more than 1000 micrometer in size

In the distribution of benthic flora, light plays a very important role when the water is sufficiently shallow. Light reaches the bottom sediments in plenty and as a result of it, benthic algae and macrophytes grow in greater abundance. Hustedt (1922), Warming (1923) and Hurter (1928), reported that the nature of the substratum is of the great importance in determining the composition of algal association living upon it. A shallow water body has greater part of water mass in the direct contact with the bottom than the deeper ones. This allows nutrients, like nitrogen and phosphorus, to dissolve more efficiently from the basin.

The distribution of the diverse fauna within waterbody is extremely heterogenous. Benthic organisms either possesses adaptive mechanisms to cope with these changes, either relatively dormant stages until more physiologically amenable conditions return, move, or die. The adaptive capabilities of the benthic animals to the dynamics of environmental parameters are basic to their distribution, growth and reproductive potential (Wetzel, 1983).

These animals are widespread in their distribution and can live on all bottom types, even on man-made objects. They can be found in hot springs, small ponds and large lakes. Some are even found in the soil beneath puddles. Many species of benthos are able to move around and expand their distribution by drifting with currents to a new location during the aquatic phase of their life or by flying to a new stream during their terrestrial phase. Most benthic species can be found throughout the year, but the largest numbers occur in the spring just before the reproductive period. In colder months, many species burrow deep within the mud or remain inactive on rock surfaces. Many aquatic insects undergo a complete metamorphosis - the transition from egg to larva to pupa and finally to adult. They remain in the water for most of their lives (typically one month to four years). After becoming adults, the majority of insects live for only a brief time, usually a few hours to a few days, while they locate mates and reproduce.

Many organisms adapted to deep-water pressure cannot survive in the upper parts of the water column. Dead and decaying matter from higher up in the water column drifts down to the depths sustains the benthic food chain. Most organisms in the benthic zone are scavengers or detritivores. The depth of water, temperature and salinity, and type of local substrate all affect what benthos is present. In coastal waters and other places where light reaches the bottom, benthic photosynthesizing diatoms can proliferate. Filter feeders, such as sponges and bivalves, dominate hard, sandy bottoms. Deposit feeders, such as polychaetes, populate softer bottoms. Fish, sea stars, snails, cephalopods, and crustaceans are important predators and scavengers.

The littoral benthos is extremely varied when compared with that of deeper region. Protozoan, sponges, coelenterates, rotifers, nematodes, bryozoans, crustaceans, molluscs, insects, annelids, echinoderms and many lower vertebrates are abundant in the shallow waters. Biglow (1928) divided the littoral benthic micro-organisms of Nipigon lake, Canada into ecological groups. The ooze films group comprises those micro-organisms living in and on the film oozes which form the upper surface of the lake bottom. The assemblage was found to contain following microscopic organisms e.g. bacteria, green algae, diatoms, protozoans, rotifers, several entomostracan (mostly cladocera), tardigrada and certain water mites.

Nonetheless, it is also clear that significant seasonal, interannual, and decadal changes of food supply to the benthos do occur, and that major climate shifts are associated with marked changes in the abundance and species composition of the epibenthic megafauna (Billett *et al.*, 2001; Ruhl and Smith, 2004; Smith *et al.*, 2006).

Microbenthic algae are known to regulate the cycle of nutrients from the sediment to the water column (Hargrave, 1972; Shaffer and Onuff, 1983; Rizzo, 1990; Wiltshire, 1992). The biomass of benthic microalgae is high and they retain a part of the newly mineralized nutrients at the sediment surface (Cartlon and Wetzel, 1988). The benthic algal productivity accounts for large percentage of total primary production in shallow estuarine water bodies (Josson, 1991).

Many species of benthos are sensitive to pollutants such as metals and organic waste. Mayflies, stone flies and caddis flies are generally intolerant of pollution. Stream macro-invertebrates have been used extensively to bio-monitor numerous environmental stresses (Rosenberg and Resh, 1993). Benthos are sensitive to watershed condition and exhibit sufficient stability in assemblage structure over time to make them useful as long term monitor of stream health (Richards and Minshell, 1992) and indicator of water quality (Gauffin and Tarwell, 1952; Wilhm and Dorris, 1968 and Resh, 1995). Hynes (1961) reported that the density of benthos in a water body is useful index of water quality although density may fluctuate widely with changes in the seasons and space. Some benthic forms are often considered to be best indicator of organic pollution because of their constant present, relatively long life span, sedentary habits and different tolerance to stress habitat (Webber *et al.*, 1989). According to Brinkhurst (1974), the community of benthic invertebrate in lake has been used as indicator of lake fertility and even been used as a basis for lake classification (Johnson *et al.*, 1993). Knowledge of littoral benthos also becomes more important because of the increasing human influence on the aquatic ecosystem. Moreover, the effect of pollution or even more the effect of the regulation of water level can not be understood or even can not be predicted without knowledge of the natural state of the littoral zone.

Despite the great importance of benthic communities in general, relatively fewer studies have been carried out as compared to plankton and nekton.

Studies which have revealed a clear cut seasonal and spatial variation in relation to sediment characteristics along west coast have been carried out by Harkantra *et al.* (1980), Devasy *et al.* (1987) and Gopalkrishna and Nair (1998). The need for comprehensive studies on benthic fauna is important for better understanding of benthic community and also in evaluating their role as fish food. The earliest and very brief records on great lakes benthos came from the works of Jackson (1844), Agassi (1850), Hoy (1872) and Stimson (1971). A brief classification of benthos was given by Warming (1895) and Gams (1918) and sessile and slowly moving epifauna have been differentiated by Petersen (1926). More information has been gathered on benthic community by Birge and Juday (1911), Allee (1912), Juday (1922), Petersen (1926) and Rawson (1930). Bigelow (1928) described ooze film layer of the bottom. Ecology and economy of benthic community was studied by Eggleton (1936), Pennak (1939), Ward (1940), Hoff (1943) and Kenk (1949). Needham (1959) published papers on culture methods for benthic invertebrate animals. Berg (1938), Meuche (1939), Roll (1939) and Mare (1942) also provided information on benthos. The biology of bottom invertebrates was studied in detail by Cooper (1969), Anderson and Day (1986), Bass and Bruce (1986), Kendall and Lewis (1986) and Lewis (1986). The correlation between benthic primary production and temperature and irradiance was studied by Colijn and Jonge (1984). Nutrients and benthic primary productivity in shallow estuarine system of Australia have been studied by Lukatelich and Comp (1986). Kutti *et al.* (2007) found that at deepwater sites, organic waste affected the benthic community on a much larger spatial scale than at shallow water sites. In temperate regions, the impacts of finfish cage farming on the surrounding environments have been studied, using with a number of different approaches, including water chemistry, plankton and macro-benthos (Chong *et al.*, 2004; Hall-Spencer *et al.*, 2006 ; Lee *et al.*, 2006) sediment chemistry and nutrient fluxes (Christensen *et al.*, 2000; Porrello *et al.*, 2005).

Benthic diversity indices were developed and used for assessing different ecological impacts. In this respect the Shannon-Wiener index H, the BQI (Benthic Quality Index) and the AMBI (Anti Marine Biotic Index) are among those indices generally used. The AMBI had been proposed for the assessment of the ecological status of estuarine and coastal waters. Whereas the BQI were mainly designed for application in marine areas. Diversity includes diversity within species and among species, and comparative diversity among ecosystems. The main purpose of all of them is to separate impacted sites from undisturbed (Borja, 2003; Muxika *et al.*, 2005). Their application, however does not necessarily allow distinguishing between natural or man-induced disturbances and their natural variability both on temporal and spatial scales has to be assessed (Vincent *et al.*, 2002).

A lot of work has been done on the benthic fauna. Some important contributions from India and abroad are those of Jackson, 1844; Aggasive, 1850; Hoy, 1872; Warming, 1895; Gams, 1918; Birge and Juday, 1911; Juday, 1922; Petersen, 1926; Daken, 1927; Rawson, 1930; Eggleton, 1936; Pennak, 1939; Ward, 1940; Kenk, 1949; Needham, 1959; Rokop, 1974; Dayton and Oliver, 1977; Pillai, 1977; Capitoli *et al.*, 1978; Bemvenuti *et al.*, 1978; Word, 1978; Feder *et al.*, 1979; Haflinger, 1981; Chandran *et al.*, 1982; Tyler *et al.*, 1982; Ordner and Lawrence, 1987; Atkinson and Wacasey, 1987; Bemvenuti, 1987; Grebmeier *et al.*, 1988; Grebmeier and McRoy, 1989; Highsmith and Coyle, 1990; Carey, 1991; Grebmeier and Barry, 1991; Uitto and Sarvala, 1991; Allan and Maguire, 1992; Tyler *et al.*, 1992; Ambrose, 1993; Blake, 1993; Prabadevi, 1994; Allan *et al.*, 1995; Ambrose and Renaud, 1995; Bacher *et al.*,1995; Hobson *et al.*, 1995; Rosenburg, 1995; Eckman, 1996; Nunes *et al.*, 1997; Piepenburg *et al.*, 1997; Ambrose and Renaud, 1997; Ritzrau and Thomsen, 1997; Focken *et al.*, 1998; Rysgaard *et al.*, 1998; Shishehchian and Yusoff, 1999; Bauerfeind *et al.*, 2000; Wollenburg and Kuhnt, 2000; Iken *et al.*, 2001; Shishehchian *et al.*, 2001; Bolam *et al.*, 2002; Cromey *et al.*, 2002a; Grant *et al.*, 2002; Hargrave *et al.*, 2002; Hobson *et al.*, 2002; Borja *et al.*, 2003; Carroll and Carroll, 2003; Chong *et al.*, 2004; Dunstan and Johnson, 2003; Klages *et al.* 2004; Lohrer *et al.*, 2004; Perus *et al.*, 2004; Ruhl and Smith, 2004; Solan *et al.*, 2004; Wenzhöfer and Glud, 2004; Dowd, 2005; Grant *et al.*, 2005; Porrello *et al.*, 2005; Cranford *et al.*, 2006; Hall-Spencer *et al.*, 2006; Lee *et al.*, 2006 and Smith *et al.*, 2006; Coyle *et al.*, 2007; Kutti *et al.*, 2007; Blanchet *et al.*, 2008; Borja *et al.*, 2008; Callier *et al.*, 2006, 2007, 2008; Dauer *et al.*, 2008; Lewis and Gripenberg, 2008; Puente *et al.*, 2008; Teixeira *et al.*, 2008; Weisberg *et al.*, 2008; Borja *et al.*, 2009.

In India several attempts have been made to study the benthic fauna by Pillai (1977), Chandran *et al.* (1982) and Prabadevi (1994). The study of benthic communities as best indicator of pollution was carried out by Venugopal (1982), Satyanarayana (1994) and Gopalkrishnan and Nair (l998).

Aims and objective of the study

Aquatic ecosystem is one of the important sustainers of biodiversity. Aquatic diversity encompasses large marine and freshwater ecosystems including estuaries, lakes, ponds, reservoirs, rivers, streams, ground water and wetlands. Being a support- system of many species (benthos, plankton, aquatic plants, insects, fish, birds and mammals) waterbodies maintain a complex ecological balance in nature. However the aquatic habitats in recent time have undergone major changes worldwide due to eutrophication and pollution resulting from agricultural activities, urbanization and climatic changes.

Benthic fauna are especially of great significance for the fisheries that they themselves act as a food of bottom feeding fishes (Walker *et al.*, 1991; Vijaykumar *et al.*, 1991) forming an important part of the food chain, thus plays a critical role in the natural flow of energy and nutrients. When benthic invertebrates die, they decay leaving behind nutrients that are reused by aquatic plants and other animals.

The usefulness of benthic organisms, especially the benthos in pollution monitoring programme to ascertain the health of estuarine and marine environments has been re-emphasized. Studies made on benthos led to the development of the indicator organism concept, which is the presence of a particular species or a group of species in a given locality reflecting the status of the environment. Among benthos, polychaetes are ideal indicator organisms, since they constitute well over half of the total number of organisms in and on the bottom and thus give a good indication of health conditions of the aquatic environment.

The salient features of Benthos are

- They are ubiquitous and they are affected by perturbations in different habitats.

- Their longevity allows temporal changes in abundance and age structure and provides long-term exposure to toxic substances as they live in close contact with sediments, which enhances their intimacy with many pollutants.

- The infaunal organisms reflect the situations not only at the time of sampling but also during year after year.

- They are species rich, so the large number of species produces a range of responses.

- They are mostly sedentary, so they stay in place, which allows determination of the spatial extent of a perturbation.

- They provide evidence of comparing the response of the diversity of each single group to environmental variables with the response of the total diversity of macrobenthos conditions over long periods of time.

The present study proposes to identify indicator species of pollution among benthos from the derelict waterbodies of Aligarh, India and explains their effectiveness as graphical tools for diversity indices in pollution-monitoring studies.

The present work includes:

1. Study of monthly variations in important physico-chemical factors
2. Study of monthly abundance of benthos, species composition and community structure in selected waterbodies.
3. Study degree of relationship between benthos density and different physicochemical factors.
4. Statistical analyses including various measures of diversity and Canonical Correspondence Analysis (CCA).

All these would be helpful in knowing the status of benthic diversity in such water bodies and their conservation from biodiversity point of view.

Chapter II

Climatology and Description of Study area

TOPOGRAPHY OF ALIGARH AND CLIMATOLOGY

Aligarh district is a part of Central Ganga Plain of the state covering an area of 5498 square kilometer. and lies between North latitudes 27°28' and 28°10' and East longitudes 77°29' and 78°36' with total population of 4,32,37,60 as per 2001 census (density: 786 persons/sq.km.). The district is bounded by river Ganga in the west and the river Yamuna in the east. The entire district falling in Upper Ganga Doab represents flat topography.

Climatic factors play an important role in the ecology of both aquatic and terrestrial environments (Barclay, 1966). These factors control organic production in lakes and rivers by affecting circulation and exchange of essential nutrients (Rawson, 1939). Panday and Tripathi (1988) have also reported the role of climatic factors in the ecology of aquatic ecosystems. For a scientific approach to aquaculture practices, the understanding of climatic factors and their interaction with the biological processes within the water body is essential. In view of all this, a brief description of the climatology of Aligarh is given here.

Aligarh experiences the tropical monsoon type of climate with marked North-East and South-West monsoons. The year can be broadly divided into

- i) Winter season (December to January)
- ii) Post-winter (February to March).
- iii) Summer season (April to June)
- iv) Monsoon season i.e. season of general rains (July to September)
- v) Post-monsoon season (October to November).

The winter season is marked with considerable fall in temperature. The nights of winters are cold (as low as 1.0°C at midnight) and the days are moderately warm. The winds are very light and mostly dry. This season experiences occasional rains.

The Post-winter season is marked with gradual rise in temperature, bright sunshine, absence of cloudy days, a gradual lengthening of the photoperiod and a lower relative humidity.

Summer season is characterised by gradual rise in temperature with absence of cloudy days and bright sunshine. Temperature gradually increases during May - June. Hot dry winds are a regular feature. These winds are locally called as **loo**. The occurrence of dust and thunderstorms caused by convection currents is a peculiar phenomenon of this season. There are no rains during the summer months except for the small amount accompanied by the thunderstorms. The wind produced waves and currents result in convective overturns and, as a result, the bottom water, richer in nutrients rises and mixes with the surface water. This mixing brings in the essential nutrients into trophogenic zone.

Summer is followed by **monsoon season**. The rains generally begin in July and last till the end of September. The season is characterized by a gradual fall in temperature. More numerous cloudy days, steady rains, relatively low light intensity, gradual shortening of photoperiod, relatively high humidity and cyclonic weather are the feature of monsoon season.

The Post monsoon season is followed by period of transition from rainy to dry and cool weather. This is the season of retreating monsoon and is termed as *post-monsoon*. This season is characterized by a further fall in diurnal and nocturnal temperatures and a gradual decrease in photoperiod and relative humidity.

DESCRIPTION OF THE STUDY AREA

Ponds directly or indirectly have an enormous ecological, commercial and socio-economic importance. They are rich in the components of bio-diversity like, flora and fauna of local, national and regional significance.

Aligarh and its adjoining areas are richly well off with hundreds of derelict ponds (>0.2 ha) which are used as drainage basin and support an extensive and regular fisheries of various kind.

The present study was carried out on three perennial derelict water bodies, namely Medical Pond, Laldiggi Pond and Chautal Pond (Locations is given in map).

MEDICAL POND (Plate- a)

The Medical Pond, locally termed as *Dhobi Ghat*, is a perennial fresh water sewage fed Pond situated at the back side of Jawahar Lal Nehru Medical college at a distance of 2 kms from the department of zoology. The Pond is almost rectangular in shape. It is shallow pond covering an area of about 0.57 ha. with its depth varying from 0.60 to 1.50 m in different seasons. Its source of water replenishment is mainly sewage effluent from Medical College through drains, the overhead tank and surface run-off from surrounding areas.

Many washermen use this pond for washing clothes, thus adding certain chemicals and colour to its water almost every day that brings certain pysico-chemical and biological changes in its flora and fauna regularly. The water of the pond is turbid due to luxuriant growth of microscopic algae, colour stains and washing chemicals used by washermen. Bottom of the pond contains mostly loose mud, sand, stones, part of dead plants, dead plankton and decayed littler deposited by trees situated on its bank. The shoreline is surrounded by Babul (*Acacia arabica*) and Neem (*Azadirachta indica*) trees.

LALDIGGI (Plate- b)

The Laldiggi Pond is a perennial freshwater, sewage-fed pond, and is situated in the residential area of Aligarh at a distance of about 1.5 km from the department of Zoology. It covers an area of 0.8 ha. The depth of the pond varies from 0.5 to 3 meters at different places. The drainage system of the pond constitutes four inlet drains which carry the waste water and sewage from the surrounding locality. A livestock, buffalo dairy shed is situated on south east bank of the pond which also supplies large quantity of excretory products. The whole shore line of this pond is also surrounded by large number of trees of Neem (*Azadirachta indica)* and Babul *(Acacia arabica*). These tall trees cover the pond in such a way that deprive the shore line area of direct sunlight during early and late hours of the day. Considerable amount of leaf litters are also found to be deposited at the littoral bottom of the pond.

It is a shallow eutrophic body of water having an irregular shore line with varying depth and area. The basin of the pond is more or less flat which is marshy in nature consisting of dead planktonic organisms, decayed leaves, sand, clay, humus, gravels and broken pieces of bricks etc.

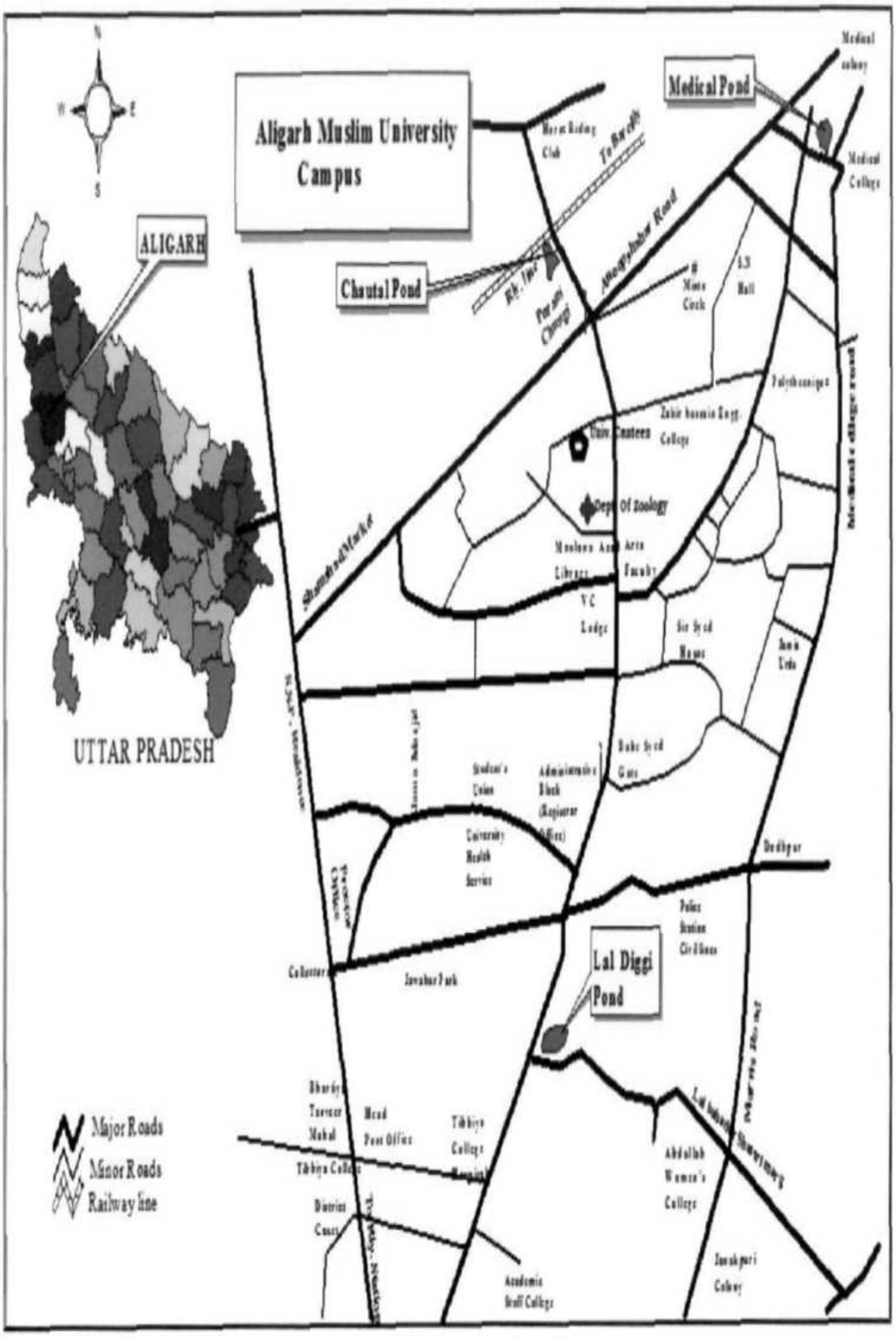
The colour of the bottom sediments ranged from brownish to grey-black, which spells a very bad smell. The water of the pond is turbid and dull greenish colour showing luxurient growth of algae throughout the year. The pond is used as drainage basin into which drainage water sweeps from the surrounding area. It is also used for bathing purpose of live-stock especially buffaloes. Human excreta and dung from the surrounding locality are washed into the pond during rainy season thereby contributing large quantities of nutrients to the pond. This pond is also characterised by presence of macrophytes like *Ranunculus sceleratus, Potamogeton, Typha angustata* and *Wolfia*. The fish fauna of this pond include *Heteropneutes fossilis, Clarias batrachus Channa punctatus* etc. The main birds of the pond include *Jul murgi, Pandub-B, Kaz, Grey Heron etc.*

CHAUTAL POND (Plate- c)

Chautal Pond is also a perennial sewage fed, eutrophic pond, situated at distance of 1.5 km from department of Zoology in South-west of Aligarh Muslim University campus. The shoreline is somewhat irregular. The depth of the pond varies from 0.5 to 3 meters at different place. The main source of its water supply is sewage water from adjoining colonies in addition to surface run-off from surrounding areas.

This pond is also used occasionally by washermen for washing clothes, thereby adding detergents and certain chemicals that bring change in its flora and fauna. The pond is characterized by rich growth of macrophytes especially water hyacinth (*Ecchornia crassipes*) which covers about 70% of the surface during the months of June and July. Other macrophytes like *Trapa, Baccopa, Polygonum* , *Wolfia* etc.

The main fish fauna of the pond include *Heteropneutes fossilis, Clarias batrachus Channa punctatus* etc. The bottom of the pond contains loose mud, stones, parts of dead plants and decayed litter.



Map showing the Study Areas

Plate a: MEDICAL POND

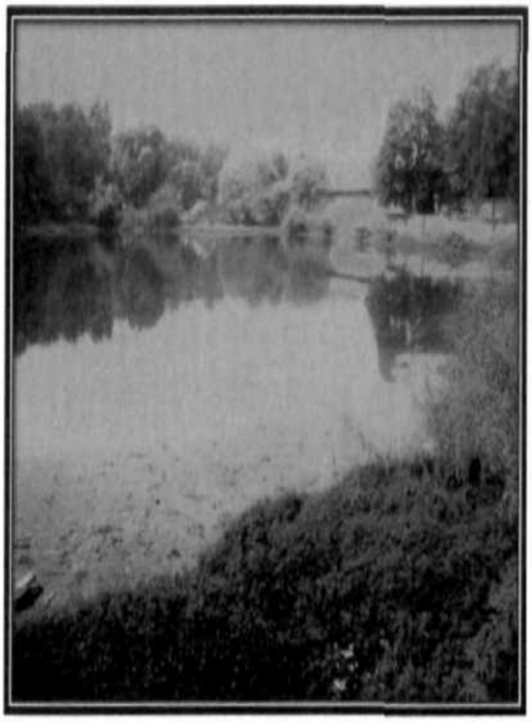


Plate b: LALDIGGI POND

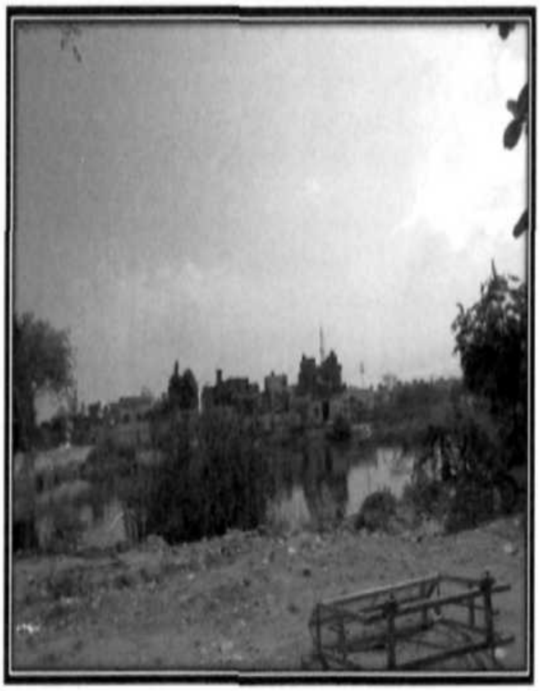


Plate c: CHAUTAL POND

Chapter III

Methodology

METHODOLOGY

A- Collection of water samples:

The subsurface water (about 30 cm depth) from littoral region of selected ponds was collected monthly with the help of Ruttner water sampler bottle with the capacity of two litters during the period, from February, 2009 to January, 2010. Parameters like Air and Water temperature, Depth, Transparency, Conductivity, pH, D.O., free CO_2, Alkalinity were analysed between 8:00 AM and 9:00 AM at the site. For remaining physicochemical analysis, water samples were filled in cleaned plastic bottles and brought to the laboratory.

B- Collection of sediment samples:

Sediment samples were collected monthly between 9:00 AM and 10:30 AM with the help of Ekman-dredge of size 15 cm x 15 cm. After collection, sediment samples were kept in plastic bags, labeled and were brought to the laboratory. A part of the sediment sample was put in oven at 105 ^{0}C for drying and grinded in a Gate-Mortar for sediment analysis.

C-Separation of bottom fauna and Identification

For benthos analysis, samples were mixed and diluted with tap water to prepare slurry in a bucket and sticks, leaves, debris were removed. Then slurry was divided into ten subsamples. Each subsample was passed through sieves, B.S. No. 30 (mesh # 500 µm) and B.S. No. 72 (mesh # 200 µm) arranged former above the latter so that smaller organisms (meio) were retained on the smaller sieve. Sieving yielded residue including mixture of animals and sediment. The sample retained on first sieve was emptied in shallow dish and organisms were sorted by using brush, forceps and pipette against a white background. To facilitate the sorting few drops of 10% aqueous solution of Rose Bangal was added. Organisms retained on second sieve were washed into a tray and then samples were taken in vials and labeled. Organisms were preserved in 70 % ethyl alcohol solution for qualitative and quantitative analysis. For larger animals, insect larvae and oligochaetes about 2 ml of preserved sample was taken in a calibrated petri-dish and studied under dissecting microscope.

For smaller organisms, about 1 ml of preserved sample was taken on Sedgewick Rafter cell and studied under an inverted microscope (Metzer). Individuals were identified up to genus or species level as could be possible and number of each taxon was noted. Density was determined per meter square area and result was expressed as ind/m^2. Identification was done with the help of keys given in Edmondson (1959), Needham and Needham (1962), Pennak (1978) and Tonapi (1980).

D- Water analysis

Physico-chemical parameters were analyzed on monthly basis from February, 2009 to January 2010 in the three selected Ponds. Each chemical parameter was repeated at least three times and the average of the three readings was taken to minimize the error.

Air and water temperatures were recorded with the help of mercury thermometer graduated up to 100°C between 8.00-9:00 am.

Conductivity was recorded with the help of digital conductivity meter (Hanna instrument, No. S250178).

The depth at the sampling sites was obtained in cm by sounding the bottom with graduated nylon rope tied to a lead weight.

Transparency, the limit up to which light can penetrate in water body, was measured by using standard Secchi-disc having diameter of 20 cm.

Dissolved oxygen (D.O.) analysis was performed at the sites by Winkler's modified technique (Trivedy and Goel, 1984).

Free carbon dioxide (CO_2) was determined by titrating 100 ml of water sample with N/44 NaOH using Phenolphthalein as an indicator (Theroux *et al.*, 1943).

pH of the water was determined at the sites by using a portable electronic digital pH meter (Hanna instrument, No. S254992).

Alkalinity was estimated by titrating 100 ml water sample with 0.02 N Sulphuric acid using Phenolphthalein and Methyl orange as indicator (Theroux *et al.*, 1943).

Hardness of water was estimated by titrating the water sample with 0.01 N EDTA solution using Murexide as an indicator (Trivedy and Goel, 1984).

Calcium and **Magnesium** present in water was estimated by titrimetric method (Trivedy and Goel, 1984).

Chloride was estimated by titrating the 50 ml sample with 0.025 N Silver nitrate using 5% Potassium chromate as an indicator (APHA, 1998).

For **Total Solids (TS)** analysis, 200 ml water sample was taken. The residue left after the evaporation of 200 ml sample of unfiltered water was taken as the amount of total solids (TS) present. The residue left after the evaporation of 200 ml sample of filtered water was taken as the amount of the **total dissolved solids (TDS)** present. The difference between TS and TDS were taken as the amount of **total suspended solids (TS-TDS=TSS)** present. The results were expressed in mg/L.

Nitrate-nitrogen (NO_3-N) was determined following the Phenol-disulfonic acid method (Triedy and Goel, 1984).

Phosphate- phosphorus (PO_4-P) was estimated by Ammonium-molybdate-blue method using stannous chloride ($SnCl_2$) as an indicator (Barnes, 1959).

E- Sediment analysis

For sediment analysis, 1:5 ratios of sediment and water were made. Twenty gm of air- dried sediment was taken in a dried beaker and 100 ml of distilled water was added to it without stirring till a glistening layer appeared on the surface of soil. Now the sample was stirred well with the help of glass rod to form a uniform paste the pH, alkalinity and water temperature of sediment were analysed as mentioned for water analysis.

Composition of Sand, Silt and Clay

The sediment samples were also analyzed according to Michael (1984) for soil texture viz. sand, silt and clay and the type of sediment texture was determined according to soil texture.

Organic matter and organic carbon

Organic matter and Organic carbon was determined by Walkley and Black methods as described by Trivedy and Goel (1984).

Five gm of over- dried sediment sample, passed through 0.5 mm nonferrous sieve, was taken in 500 ml conical flask. To this, 10.0 ml of 1N $K_2Cr_2O_7$ solution and 10 ml of conc. H_2SO_4 were added and mixed thoroughly by gentle swirling. The whole content was kept for 30 minutes to complete the reaction. After the reaction was over, 200 ml of distilled water and 10.0 ml of phosphoric acid was added followed by 1.0 ml Diphenylamine as an indicator. The whole content then was titrated with 0.4N Ferrous ammonium sulphate. A blank was also used with the same quantities of chemicals but without sediment. Calculation was made using following formulae:

$$\% C = 3.951/g\,(1 - T/S)$$

$$\% \text{ organic matter} = \% C \times 1.72$$

Where g = weight of sample in gm,

S = ml of ferrous ammonium sulphate solution used in blank titration,

T = ml ferrous ammonium sulphate solution used in sample titration.

(The factor 1.724 is based on the assumption that carbon is only 58 % of the organic matter).

Diversity

For Benthic species diversity following measures of diversity were analysed:

Shannon-Wiener's Index (Ludwig and Reynolds, 1988)

$H = -(\Sigma\, pi \ln pi)$; where

$Pi = n/N$

n = total number of individual of a taxon

N = total number of individuals of all taxa

Percentage similarities Sorenson's index (Sorenson, 1948) formula

$Cs = \frac{2C}{a+b} \times 100$; where

C= species common in two samples

a= number of species of one collection

b= number of species of next collection

Menhinick's Index (Menhinick, 1964)

$Dmn = S/\sqrt{N}$;

Where; S= Total number of species

N= total density of all the species

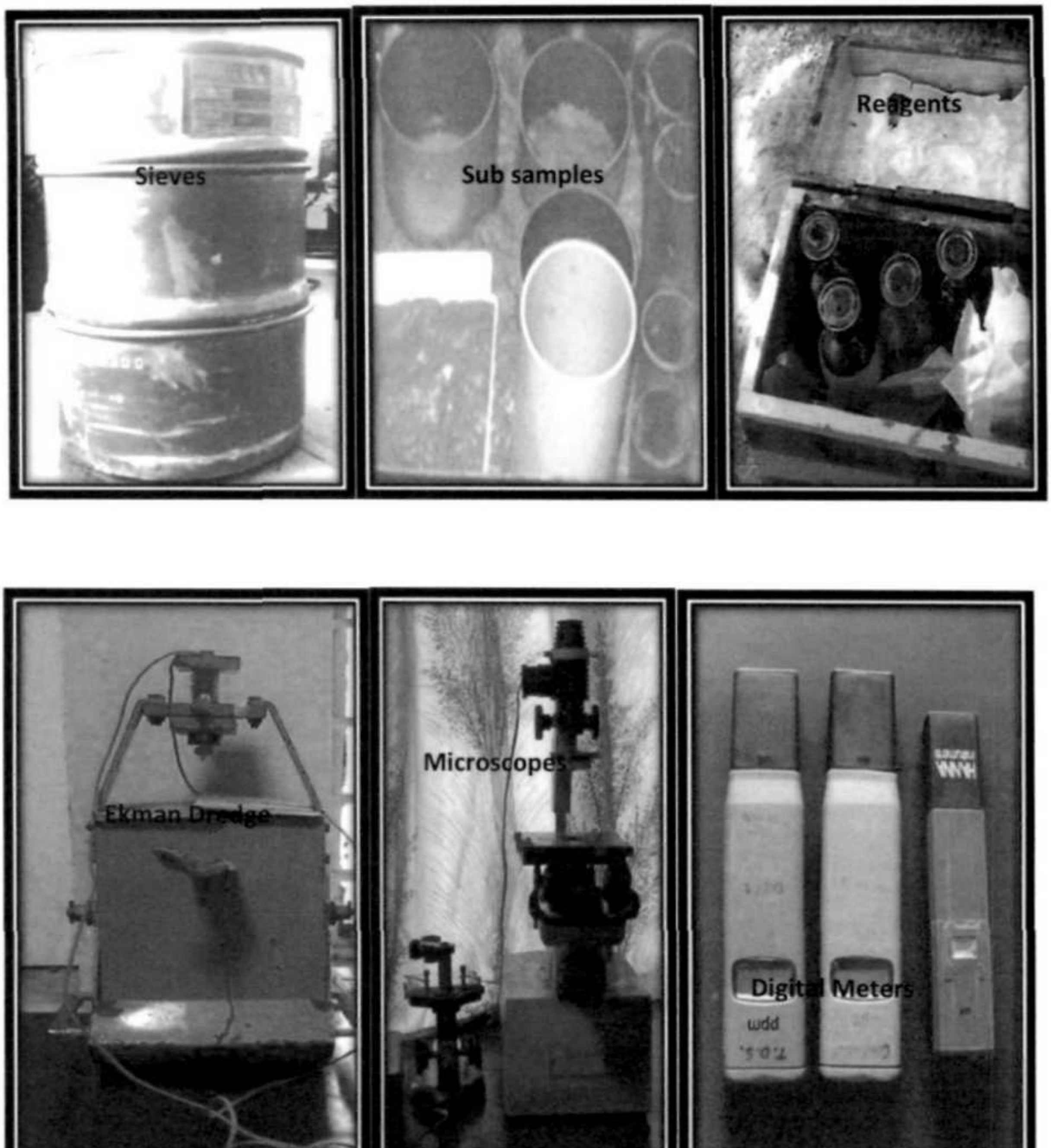
Evenness

$E_1 = H^1 / \ln S$ (Pielou, 1969);

Where H^1= species diversity

S= species richness

Statistical analyses: diversity indices, Cluster analysis, MDS and Similarity were calculated and plotted with the help of Primer v5 (version 5.2.4). Correlation analysis, Regression lines were calculated with the help of SPSS (v20). Pi figures, Histograms were plotted with the help of Microsoft excel (2007).


Sieves
Sub samples
Reagents
Ekman Dredge
Microscopes
Digital Meters

Chapter IV

Results and Discussion

Part 1

Physicocemical Conditions

1. PHYSICO-CHEMICAL CONDITIONS

Fresh water habitats occupy a relatively small portion to earth's surface as compared to marine habitats but their importance to human being is far greater than their space area because they are most convenient and cheapest source of water for domestic and industrial needs. The distribution and abundance of benthic fauna in a water body are influenced by many physico-chemical parameters of overlying water and sediment and it is difficult to correlate them with a single such parameters. Some important factors affecting the distribution of benthic fauna are depth of overlying water, temperature, dissolved oxygen, hardness, sediment texture, conductivity, transparency, carbon d ioxide, total dissolved solids and organic matter in the sediment as discussed by various workers (McLachalan and McLachalan, 1971; Kurian *et al.*, 1975).

Nearly all facets of the life-history of benthic invertebrates, and consequently their distribution and abundance are influenced by temperature (Wetzel, 2001., Vivas *et al.*, 2002; Hieber *et al.*, 2005), substrate type and composition (Allan, 1995; Hieber *et al.*, 2005), hydraulic conditions (Allan, 1995; Vivas *et al.*, 2002) and food availability (Basaguren *et al.*, 1996; Gonza´ lez *et al.*, 2003) combined and acting in various spatio-temporal scales and gradients (Cortes, 1992; Grac¸a *et al.*, 2004; Murphy and Davy- Bowker, 2005). In natural water courses, altitude, slope, channel stability, width, depth, pH, conductivity and salinity vary seasonally and/or over downstream gradients, and their relative importance affecting benthic macroinvertebrates differs (Grac¸a *et al.*, 2004).

1.1TEMPERATURE

Introduction:

Temperature constrains the various processes in aquatic ecosystems differently and therefore, a general warming of the water column will change trophic interactions and ecosystem functioning (Beaugrand and Reid, 2003; Alheit *et al.*, 2005). Increasing temperatures could also change the balance between pelagic and benthic secondary production. Sedimentation rate of organic matter during the spring bloom has been shown to decrease due to higher zooplankton grazing effect and bacterial respiration in the water column if the temperature increases (Keller *et al.*, 1993 and Müren *et al.*, 2005). Thus, the total sedimentary input to sustain the benthos may decrease if more material is channeled through the pelagic grazing food chain (ErikssonWiklund *et al.*, 2009). Higher bottom water temperatures will also increase pelagic microbial remineralisation of the settling particulate organic matter and this effect will be more pronounced in the deeper water column and the longer the sinking material is exposed to pelagic respiration (Hansen and Bendtsen, 2006). Changes in the temperature could probably also change the species composition of the benthos according to their feeding ecology (Coyle *et al.*, 2007). While benthic filter feeders have first access to the sedimenting food and therefore probably will be less affected by a lower food supply, deposit feeders are more likely to experience food limitation (Josefson and Conley, 1997). Altogether, increasing temperatures may alter the functioning of all trophic levels in a cascade from the primary producers to the higher trophic levels such as fish (Alheit *et al.*, 2005).

In an aquatic ecosystem, the influence of temperature is due to the fact that the body temperature of aquatic organisms varied with and is almost the same as that of the environment. A rise in temperature of the water leads to the speeding up of the chemical reactions in water, reduces the solubility of gases and amplifies the taste and odour (Trivedy and Goel, 1984). According to Kumar *et al.* (1996), temperature is one of the most important factors in aquatic environment, since it regulates various physico-chemical as well as biological activities. Change in temperature govern water mixing, turbulence, formation of currents (Birge, 1916; Hutchinson, 1957 and Ruttner, 1963) and biological processes like the growth, development, reproduction and other life processes of biota (Wetzel, 1983). Fluctuation in temperature of an aquatic medium regulates the biological composition of that ecosystem (Banerjee *et al.*, 1989). The disease resistances in fishes also decrease with temperature.

The temperature of natural water systems is governed by many factors. It depends mainly on the depth of water body, climate and topography. Solar radiations have an impact on the surrounding temperature. The changes in the surface temperature are directly related to the sunshine and hence, it follows closely the changes in the atmospheric temperature. Climatic condition and topography of a place directly influence water temperature and thus, the productivity of aquatic ecosystem as a whole (Welch, 1952; Hutchinson, 1957 and Kant and Raina, 1990). According to Munawar (1970) solar radiations have an impact on the ambient temperature. The level of distribution of gases and nutrient cycles along with the other biogenic processes get affected by the change in temperature of environment (Welch, 1952).

A great deal of work has been done on the thermal properties of freshwater ecosystem. Some important contributions are those of Ganapati (1956, 1960), Reid (1961), Zaffar (1966), Hutchinson (1967), Larson (1972), Vasishat and Sharma (1975), Chourasia and Adoni (1985), Kaushik *et al.* (1989), Kant and Raina (1990), Vijay Kumar (1996), Zhou *et al.* (2000), Weisse (2003), Vanderketkhoul *et al.* (2005), Heide *et al.* (2006), Elliot, and May (2008) and Shafiq (2009).

Result and Discussion:

Variations in air and water temperature of all the selected water bodies are given in Table 1a, 2a and 3a. The air temperature varied from a minimum of 15°C in January, 2010 to a maximum of 37°C in June, 2009 in the selected ponds. In Medical Pond, air temperature fluctuated from a minimum of 15°C in of January, 2010 to a maximum of 36°C in July, 2009. In Laldiggi Pond, it ranged from a minimum of 15°C in January, 2010 to a maximum of 36°C in June, 2009. In Chautal Pond, it varied from a minimum of 16°C in January, 2010 to a maximum of 37°C in June, 2009.

Water temperature varied from a minimum of 12°C in January, 2010 to a maximum of 34°C in the months of June and July, 2009 in the selected ponds. The water temperature fluctuated from a minimum of 14°C in January, 2010 to a maximum of 34°C in the months of July, 2009 in Medical Pond. In Laldiggi Pond, it varied from minimum of 12°C in January, 2010 to a maximum of 33°C in June, 2009. In Chautal Pond, it ranged from a minimum of 13°C in January, 2010 to a maximum of 34°C in June, 2009. Water temperature recorded a very significant positive correlation with Air temperature in all the three selected ponds (Medical Pond: $r = 0.996$; Laldiggi Pond: $r = 0.985$; Chautal Pond: $r = 0.995$, (Table- 8; Fig.- 1), with total solids (Medical Pond: $r = 0.758$; Laldiggi Pond $r = 0.907$; Chautal Pond: $r = 0.746$, Table- 8; Fig- 3) and total dissolved solids (Medical Pond : $r = 0.542$; Laldiggi Pond: $r = 0.931$; Chautal Pond: $r = 0.689$) in all the selected water bodies (Table- 8).

Perusal of Table-1a, 2a, 3a (Fig.-34D) reveals that the ambient temperature recorded a sharp fall during winter and concordant increase towards the summer season. The temperature fall was observed to be more pronounced in January, 2010. Fall in air temperature during winter in present study may be attributed to shorter photoperiod/ day length, oblique incident rays and increased condensation due to higher percentage of water vapors in air. The observations are in agreement with the findings of Kour (2002) and Zuber (2007).

Higher air temperature during summer months may be attributed to vertical incident rays and heating up of atmosphere as a result of absorption of heat by suspended particles (Welch, 1952; Munawar, 1970; Kaushik and Saksena, 1999; Zuber, 2007), increased photoperiod/day length, excess of short wave radiations and shifting of pressure belts.

In present investigation peak values of water temperature were recorded during summer which could be attributed to increase in day length/ photoperiod and decline in water level due to evaporation and presence of solids.

The observations are in complete agreement with the findings of Seghal (1980). The decline in water temperature in winter could be attributed to decrease in day length/photoperiod, presence of suspended planktonic/organic matter (Butler,1962 and Zuber,2007) and increased turbidity due to human activities.

In the present study, it was found that the surface water temperature of all the three water bodies follow the changes in air temperature and was always lower than air temperature.

The pattern of seasonal fluctuation in air and water temperature largely agrees with the change in solar radiation and photoperiods during different seasons. Cold, dry and hot wind waves bring variation in air temperature during different seasons (Moss, 1969).

1.2 LIGHT CONDITIONS

Introduction:

Light is one of the most important ecological factors that determines the distribution and abundance of organisms in water. Penetration of light in an aquatic habitat mainly depends upon the clearness of the water. Hence the amount of dissolved and suspended substances present in the water determine extent which light can penetrate. The daily alteration of light and darkness stimulate a rhythm in the activities of aquatic organisms. Light is essential for photosynthesis and some higher aquatic animals even require it for feeding. According to Wetzel (1983) transparency of water allows light penetration, which has far reaching effects on all aquatic organism including their development, distribution and behaviour etc. Therefore, light is often an important limiting factor in the development and distribution of flora and fauna in aquatic habitat. The transparency of water body depends upon the turbidity (Chandler, 1944; Hutchinson, 1975; Haque, 1991) which is caused by dissolved substances and suspended matter, both living and non-living. Light availability at depth is affected directly by the presence of TSS and plankton in water column and by macrophytes and sediment accumulation on the surface (Carter and Rybicki, 1985). According to Hutchinson (1975) transparency, the depth to which light penetrates in water body can be used as a reliable indicator of productivity. Transparency acts as an index of water quality and plays a key role in reflecting the pond productivity (Mohanty, 1999).

Result and Discussion:

The monthly variations in the transparency values of all the three selected ponds are given in Table-1a, 2a and 3a. The Secchi disc transparency ranged from a minimum of 17.50 cm in June, 2009 to a maximum of 57.50 cm in February, 2009 in the selected water bodies. In Medical Pond, Secchi disc transparency values varied from a minimum of 17.50 cm in June, 2009 to a maximum of 45.0 cm in March, 2009. Laldiggi Pond showed a range from 20.0 cm - 57.50 cm with minimum values recorded in June, 2009 and maximum in February, 2009. In Chautal Pond, the transparency values fluctuated from a minimum of 25.0 cm in June, 2009 to a maximum of 47.0 cm in March, 2009. Transparency recorded negative correlation with TDS (Medical Pond: $r = -0.472$; Lal diggi Pond: $r = -0.610$; Chautal Pond: $r = -0.499$) and with water temperature (Medical Pond: $r = -0.768$; Lal diggi Pond: $r = -0.641$; Chautal Pond: $r = -0.745$) in all the three selected water bodies (Table- 8).

In the present investigation, the high transparency values were recorded in post monsoon and winter which could be attributed to the low biological activities and least entry of suspensions through soil erosion or surface run off. Kumar (1990), Sharma (1999), Baba (2002) and Zuber (2007) also recorded high values of transparency in winter.

The low transparency during summer and monsoon in present study are mainly due to evaporation of water, which causes concentration of dissolve solids at high temperature and production of plankton whereas low transparency values during monsoon was due to entry of huge amount of suspended and colloidal matter, silt and clay into these Ponds along with the rain water from surrounding areas. Zuber (2007) also recorded decline in transparency during monsoon.

Kant and Raina (1990) and Kaushik and Saxena (1999) have also reported similar results with regard to the transparency of water in different water bodies in the country. However, all these Ponds, like other drainage basins, are usually low in transparency (Hutchinson, 1975). Due to high turbidity affected by inflow of waste water along with sewage effluents throughout the year and diverse populations during different months. The variations in transparency with season has been worked out by many workers (Clarke, 1938; Rawson, 1951; Hutchinson, 1957; Jhingram; 1975; Kundangar and Zutshi, 1985; Hassan *et al.*, 1998; Nath, 2001; Baba, 2002; Singh, 2004 and Zuber, 2007) who assigned the variability in transparency to primary reasons viz; autochthonous and production of plankton which may impede light penetration and suspended organic matter which result in turbidity and check light penetration.

1.3 ELECTRICAL CONDUCTIVITY

Introduction:

Conductivity is the measure of capacity of a substance or a solution to conduct electric current. Conductivity is an important factor which gives an indication of total salt concentration. Fresh water bodies in their natural state have very low conductivity values whereas polluted water shows higher values of conductivity (Trivedy *et al.*, 1985). Electric conductivity increases as the amount of ions increases, thus it is directly related with the amount of total dissolved solids. It is influenced or controlled by the chemistry of watershed soils, size of watershed, run-off from roads, atmospheric input of ions, evaporation of water, bacterial metabolism etc. The conductivity values are the indication of the total nutrient status of the water bodies; therefore, this parameter is used to indicate the trophic status. Therefore, it is considered as an index of the total dissolved solids (Sreenivasan, 1964).

Result and Discussion:

The monthly variations in the values of conductivity are given in Tables- 1b, 2b, 3b. The values of conductivity ranged from a minimum of 803 μScm^{-1} to a maximum of 1789 μScm^{-1} in the selected water bodies. In Medical Pond, it varied from a minimum of 803 μScm^{-1} in March, 2009 to a maximum of 1789 μScm^{-1} in July, 2009. In Laldiggi Pond, showed the minimum values of 978 μScm^{-1} in June, 2009 to a maximum of 1678 μScm^{-1} in January, 2010. In Chautal Pond, values of conductivity fluctuated from a minimum of 998 μScm^{-1} in December, 2009 to a maximum of 1691 μScm^{-1} in May, 2009. Conductivity recorded a non - significant correlation with TDS in all the three selected Ponds (Medical Pond: r = 0.474; Laldiggi Pond: r = -0.397; Chautal Pond: r = 0.327) (Table- 8).

In the present study high conductivity value were recorded in all the seasons. The maximum conductivity values during winter may be due to decrease in phytoplankton population leading to increase in major ion concentration in aquatic medium (Juday and Birage, 1933; Rhode, 1949; Otsuki and Wetzel, 1974).

The present observation is in agreement with the findings of NIH (1998) but is in total contrast to the result obtained by Wanganeo (1998).

Higher values of conductivity in selected ponds were due to the continuous entry of the sewage from the catchment area in addition to weathering of the rocks and sedimentary deposits due to the presence of carbon dioxide in monsoon rains (Likens *et al.*, 1972; Kilham 1975; Likens, 1985 and Wu and Gibson, 1996) and washing of atmospheric salts by rains (Caroll, 1962; Barica and Armstrong, 1971; Lesack and Melack 1991). The increase in value of conductivity during monsoon gets reinforcement from findings of Kilham (1975) and Gibson *et al.* (1995).

1.4 pH

Introduction:

The pH is very important chemical characteristic of natural water and is closely related to many biological phenomena, mineralization, oxidation and reduction in water bodies. pH indicates the concentration of hydrogen ions in water. It expresses the intensity of acidity or alkalinity depends upon the amount of absorbed CO_2, on H^+ ion arising from the dissociation of carbonic acid (H_2CO_3) and OH^- ions arising from the hydrolysis of bicarbonates buffering the water. According to Welch (1952) it is an important means of understanding the chemical conditions prevailing in the natural waters. pH of water is considered to be one of most important chemical factor affecting the productivity of the water body. In general pH is influenced directly by the carbon dioxide concentration in the water, which in turn regulates photosynthetic and respiratory activities (Talling, 1976).

However, the range of pH tolerance varies among different species. Biological conditions become better when pH of aquatic environment is constant. The pH of water body depended on the flow of effluents with high alkalinity, and the assimilation of the carbon dioxide reserve in it. Therefore, the determination of pH may serve as an index of other environmental conditions, like quantity of CO_2 and O_2.

Verma and Shukla (1970) believed that the pH would prove to be an ecological factor of major importance in controlling the activities and distribution of aquatic flora and fauna. However, Mehra (1986) suggested that pH of environment has little or no importance. To achieve good fish production, pH of water should be monitored regularly to ensure it optimum range.

Alikunhi (1957) has demonstrated that pH between 6.5- 8.5 with large variations play a pivotal role in the productivity of water. pH range from 5 to 6.6 and 9.1 to 11.0 results in low productivity (Sreenivasan, 1964). According to Vegas-Villarubia *et al.*, (1988) low alkalinity and pH values are indicators of low mineralization and high humic substances. Bell (1991) has stated that pH range between 6.5 to 9.0 provide an adequate environment for the well being of freshwater fish, bottom dwelling invertebrates and fish food organisms. pH between 6.5 and 9.0 supports good fishery (Das *et al.* 2001).

Result and Discussion:

In present study, pH of water fluctuated from 7.8 to 9.5 (Table -1c, 2c and 3c; Fig.-34C) throughout the course of study. In Medical Pond, it varied from a minimum of 8.5 in January, 2010 to a maximum of 9.5 in July, 2009. In Laldiggi Pond, it fluctuated from a minimum of 8.0 in April, 2009 to a maximum of 8.9 in December, 2009. In Chautal Pond, it ranged from a minimum of 7.8 in September, 2009 to a maximum of 8.5 in April, 2009. pH of sediment fluctuated from 7.5 to 9.6 (Table -1c, 2c and 3c) throughout the course of study. In Medical Pond, it varied from a minimum of 8.4 in December, 2010 to a maximum of 9.6 in June, 2009. In Laldiggi Pond, it fluctuated from a minimum of 8.0 in July, 2009 to a maximum of 9.2 in December, 2009. In Chautal Pond, it ranged from a minimum of 7.5 in September, 2009 to a maximum of 8.7 in April, 2009. Statistically pH showed Positive correlation with total alkalinity in Medical Pond ($r = 0.783$) and Chautal Pond ($r = 0.203$) and negative but significant correlation in Laldiggi Pond ($r =- 0.635$) (Table-8).

The higher values of pH were recorded throughout the course of study at all the selected ponds excepting for few months. The reason for high pH in present study could be related to enhanced photosynthesis carried out by phytoplankton and macrophytes, thereby, removing free CO_2 and resulting in increase an alkalinity in all ponds. During the same process, bicarbonates are converted into carbonates and hence pH is raised. The findings are in conformity with the findings of Parveen (2003). The decrease in pH in some months was probably due to release of anaerobic water affected by the decomposition of concentrated organic matter and respiration of biota. The findings are in conformity with earlier study of Sreenivasan (1964). Moreover, pH remained on alkaline side throughout the study period. The alkaline pH at all the selected site, confirmed the earlier findings of Singhal *et al.* (1986) and Shastree *et al.* (1991) that most of the freshwater in the Northern India, showed alkaline pH range.

1.5 DEPTH

Introduction:

Depth of a pond has an important bearing on the physical and chemical qualities of water. It determines the temperature, circulation pattern of water and the extent of photosynthetic activity. The seasonal and spatial differentiation in the meteoric rains are the factors responsible for balancing the depth (Augustyn, 1979) and it varies from year to year (Kant and Anand, 1979) depending upon the monsoon rains, evaporation, siltation and water abstraction. The water depth thus, fluctuates seasonally causing seasonal irregularities.

In shallow ponds, sunlight penetrates up to the bottom, warms up the water and facilitates increase in productivity. Generally a depth of about meter is considered congenial for the biological productivity of ponds.

Result and Discussion:

The monthly variations of depth in the selected water bodies are given in Tables 1a, 2a and 3a. The depth ranged from 41.0 cm to 169.0 cm of the selected ponds during the course of study. Medical Pond showed the minimum depth of 41.0 cm in June, 2009 to a maximum of 169.0 cm in August, 2009. In Laldiggi Pond, it fluctuated from a minimum of 57.0 cm in June, 2009 to a maximum of 149.0 cm in September, 2009. In Chautal Pond, depth varied from a minimum of 51.0 cm in June, 2009 to a maximum of 99.0 cm in September, 2009.

During present study, depth of selected ponds recorded decreasing during summer while increasing during monsoon. Rise in water level during monsoon as a consequence of rain has also been reported by Singh (2004). The fall in water level/depth during summer season may be attributed to high rate of evaporation due to high ambient temperature. Singh (2004) also pointed out evaporation of water due to high temperature as possible factor in the fall in depth during summer.

The perusal of Tables-1a, 2a, 3a reveal that these water bodies are subjected to wide seasonal fluctuations owing to variations in precipitation and evaporation, which in turn cast their influence on the depth of these ponds. Furthermore, depth has been observed to have a bearing on the physico-chemical parameters of water as well (Gochhait, 1991), hence the metabolic activities of biotic communities seem to be greatly related and influenced by depth of water.

1.6 SOLIDS IN PONDS

In all water bodies total solids (TS) represent both total suspended solids (TSS) and total dissolved solids (TDS). Total solids in water are due to inorganic and organic substance including both dissolved and suspended particles like slit, clay and plankton. Higher amounts of total solids cause turbidity and so reduce the light penetration affecting water quality indirectly and imbalance in the aquatic life (Kaushik and Saxena, 1999).

All polluted water bodies have higher quantities of total solids. Many workers have reported wide variations in the TS from different parts within and outside the country (Welch, 1952; Hutchinson, 1957, 1975; Wetzel, 1975, Kaushik *et al.*, 1989; Kaushik and Saksena, 1999, Kumar, 2002; Verma and Sharma, 2002 etc.).

TOTAL DISSOLVED SOLIDS (TDS)

Total dissolved solids referred to as the sum total of inorganic salts of calcium, magnesium, sodium, potassium, carbonate, bicarbonate, chloride, sulphate and small amount of organic matter present in water, which influence the taste and palatability of drinking water (WHO, 2003). They are also utilized by organisms, thus make a useful parameter in determining the productivity of ponds and lakes (Welch, 1952; Reid, 1961; Hutchinson, 1975; Wetzel, 1975).

Although high concentration of TDS near 3000 mg/l may also produce distress in livestock and cattle (Trivedy and Goel, 1984). However, no recent data on the effect of TDS on the health is available, yet in early studies inverse relationship was observed between TDS concentration in drinking water and the incidence of coronary heart disease (Schroeder, 1960), arteriosclerotic heart (Schroeder, 1966), Cardiovascular disease (Sauer, 1974) and cancer (Burton and Cornhill, 1977).

TOTAL SUSPENDED SOLIDS (TSS)

Total suspended solids (TSS) include the substances, which impart turbidity to water thereby reducing transparency. TSS in water bodies are contributed by particles of different size ranging from coarse to fine colloidal particles of various organic complex and plankton (Shastree *et al.*, 1991). TSS in these ponds consists of organic and inorganic particles. Inorganic solids such as clay slit and other soil constituents are common in these ponds. Among organic materials such as plants fibers and biological solids, algal cells, bacteria etc. are also common constituents of these ponds. Various workers have reported wide fluctuations in the range of TSS (91-2080 mg/l) in ponds, reservoirs and tanks (Ganapati, 1956; Singhal *et al.* 1986; Shastree *et al.* 1991; Kaushik and Saxena, 1999).

Result and Discussion:

In present study, TS ranged from 1210 mg/l to 3050 mg/l, Tables-1b, 2b, 3b in all the three selected ponds. Medical Pond showed the minimum value 1526 mg/l in January, 2010 and maximum 2900 mg/l in August, 2009. In Laldiggi Pond, values fluctuated from a minimum of 1400 mg/l in December, 2009 to a maximum of 2970 mg/l in July, 2009. Chautal Pond Showed the minimum value 1210 mg/l in December, 2009 and maximum 3050 mg/l in September, 2009. Statistically total solids recorded a very significant positive correlation with water temperature (Table- 8; Fig.- 3) in all the three selected ponds (Medical Pond: r = 0.758; Laldiggi Pond: r =0.907 and Chautal Pond: r = 0.746), indicating temperature as one of the important factors responsible for concentration of solids.

In present study, TSS ranged from 340 mg/l to 1200 mg/l, (Tables1b, 2b, 3b) in the selected ponds. Medical Pond showed minimum value of 450 mg/l in June, 2009 and maximum 950 in August, 2009. In Laldiggi Pond, it fluctuated from a minimum of 340 mg/l in November, 2009 to a maximum of 1200 mg/l in August, 2009. Chautal Pond showed minimum value of 395 mg/l in February, 2009 and maximum 915 mg/l in September, 2009. Statistically TSS showed negative correlation with transparency (Medical Pond: r =- 0.187; Laldiggi Pond: r =-0.262; Chautal Pond: r =-0.569) (Table- 8).

The values of TDS ranged from a minimum of 700 mg/l to a maximum of 2200 mg/l in the selected ponds. Medical Pond, showed a minimum value of 920 mg/l in December, 2009 and maximum 2010 mg/l in September, 2009. In Laldiggi Pond, TDS values fluctuated from a minimum of 950 mg/l in December, 2009 to a maximum of 2200 mg/l in June, 2009. In Chautal Pond, values varied from a minimum of 700 mg/l in November, 2009 to a maximum of 2135 mg/l in September, 2009. Statistically TDS showed negative correlation with dissolved oxygen in Laldiggi Pond (r =-0.631) and Chautal Pond (r =-0.446) but in Medical Pond it showed positive correlation (r =0.510) (Table – 8). TDS showed positive significant correlation with water temperature (Medical Pond: r = 0.542; Laldiggi Pond: r =0.931; Chautal Pond: r =0.689) (Table – 8). With the increase in temperature the decomposition and mineralization processes increase, releasing nutrient in the water.

In present investigation higher values of total solids were recorded throughout the course of study though peak values were recorded in monsoon and summer. The monsoon maxima in present study could be attributed to, increased inflow of suspended solids in the form of eroded soil particles from the shore line, discharge through drains and input through surface run-off and wastage, whereas summer maxima could be related to high evaporation rates, release from autogenic and biogenic sources and sedimentation. In present study high values of the TSS were recorded during Monsoon month which could be attributed to silt, clay and other particles entering into these ponds along with surface run-off during this season and washermen's activities for cleaning clothes using certain chemicals, stains and other colouring substance which help in increasing TSS.

The findings are in full agreement with the observation of Kaushik and Saxena (1999) who recorded maximum values of TSS during monsoon.

Lower values of TSS during winter were due to sedimentation and slow decomposition rate during winter.

In present investigation, high values of TDS were recorded throughout the course of study though peak values of TDS were recorded in monsoon and summer. The maximum values of TDS in monsoon in present study can be attributed to increase in the load of soluble salts, mud, humus, nutrients, etc, in the surface run-off entering in to these ponds and increase in dissolved organic matter (Strom, 1947).

These observations are in conformity with the findings of Boralkar (1981) and Gochhait (1991) who recorded maximum values of TDS in monsoon but in confrontation with the study of Gonzalves and Joshi (1946) and Tripathi and Pandey (1990) who recorded decline in values of TDS during monsoon.

High values of TDS were also recorded during summer in present study which could be due to higher decomposition rate, release of nutrients from the sediment and excessive evaporation at high temperature causing concentration of dissolved solids. Gonzalves and Joshi (1946), Tripathi and Pandey (1990) and Gochhait (1991) also recorded an increased concentration of TDS during summer.

The minimum values of TDS were recorded in winter during the course of study, which could be related to their utilization by plankton and other aquatic plants and loss of nutrients into the sediment during this cool and calm period. The present observations are in full agreement with the findings of Tripathi and Pandey (1990) and Gochhait (1991) who recorded decline in TDS concentration during winter.

Water bodies with high TDS have bean reported to be productive than those with low values (Welch, 1952; Northcote and Larkin 1956).

1.7 DISSOLVED OXYGEN

Introduction:

Dissolved oxygen is essential for the respiratory metabolism of organisms. The amount of DO in a water is only one fortieth to the twentieth of that present in equal volume of air when the two are in equilibrium although their partial pressure are the same. The distribution of O_2 in the aquatic medium is governed by diffusion from air, photosynthesis of micro and macrophytes and loss due to respiration and chemical and biotic oxidation. Generally the water masses show high fluctuation in the oxygen content during day and night. Thus the O_2 regime exhibits both diurnal and seasonal variations and that many environmental parameters influence the concentration of the O_2 content in an aquatic environment. Most of the organisms except anaerobic bacteria need oxygen. Dissolved oxygen is one of the most important parameter in water quality assessment and reflects the physical and biological process prevailing in the waters. Its presence is essential to maintain higher forms of biological life in water. The effects of waste discharge in the water body are largely determined by the oxygen balance of the system (Trivedy and Goel, 1984). The rates of supply of dissolved oxygen from the atmosphere and from the photosynthetic inputs and the hydro-mechanical distribution of oxygen are counter balanced by consumptive metabolism by biota and non-biotic chemical reactions.

Dissolved oxygen influences many chemical and biological reactions and thus, is important for the hydrochemistry of aquatic ecosystem. It directly affects the survival and distribution of fauna and flora in an ecosystem (Vijay Kumar *et al.*, 1999). Aquatic organisms have specific requirement of oxygen (Trivedy and Goel, 1984).

The concentration of oxygen also reflects whether the processes undergoing are aerobic or anaerobic. Low oxygen concentrations are generally associated with heavy contamination by organic matter. Higher concentration of dissolved oxygen in water is an indication of better health and constantly high content allows a water body to support more members and variety of aquatic organisms (Parveen, 2003). Tarzwell (1957) has suggested that a minimum of 3.0 mg/l dissolved oxygen is necessary for healthy fish life. George (1961) has mentioned that the concentration of 1.4 mg/l is sufficient to maintain life in water. According to Das *et al.* (1995) dissolved oxygen concentration greater than 5.0 mg/l favours good growth of fauna and flora.

Result and Discussion:

The monthly variations in dissolved oxygen concentration of all the selected water bodies are given in Tables -1a, 2a, 3a (Fig.-34B). Dissolved oxygen varied from 3.0 mg/l to 10.0 mg/l in the selected water bodies. In Medical Pond, the value of dissolved oxygen fluctuated from a minimum of 3.6 mg/l in July, 2009 to a maximum of 10.0 mg/l in December, 2009. Laldiggi Pond, showed variations from a minimum of 3.1 mg/l in October, 2009 to a maximum of 8.0 mg/l in January, 2010. Chautal Pond, it ranged from a minimum of 3.0 mg/l in July, 2009 to a maximum of 8.2 mg/l in January 2010. The observations are in conformity with the findings of Singh (2004). Statistically D.O. showed negative and significant correlation with water temperature in all the three selected ponds (Medical Pond: $r = -0.853$; Laldiggi Pond: $r = -0.811$ and Chautal Pond: $r = -0.577$), indicating temperature as one of the important factors for variations in D.O. concentration in all the water bodies (Table - 8; Fig.- 2).

Dissolved oxygen concentration is affected by many factors like solubility of oxygen in water, intensity of light, loss due to chemical and biological oxidation, diffusion and absorption from the atmosphere, the presence of green aquatic organisms and photosynthesis (Wetzel, 1983). Perusal of tables-1a, 2a, 3a reveals that high dissolved oxygen values were recorded during winter which could be related to increased oxygen retention capacity of water at low temperature (Jhingran, 1975; Adoni, 1985) and reduction in respiratory consumption of oxygen due to reduced metabolic rate. Present results agreed with the findings of Dalpatia (1998) and Singh (2004). As the water warms up its capacity to hold oxygen is reduced and oxygen may be released in to the atmosphere. Therefore, the solubility of O_2 depends upon thermal regime of water body and often it exhibits an inverse correlation.

The decline in dissolved oxygen content during summer in present study could be attributed to ever increasing water temperature leading to decrease in oxygen retention capacity of water (Gochhait, 1991; Singh 2004),death and decomposition of organic matter (Clarke, 1954) and increase in respiratory consumption of oxygen due to increased metabolic rate.

1.8 FREE CARBON DIOXIDE (CO_2)

Introduction:

Carbon dioxide is an extremely important constituent of an aquatic environment (Welch, 1952). This gas is very much necessary for bacterial growth and green plants. The primary source of inorganic carbon for photosynthesis and the generation of organic substance in an aquatic ecosystem are largely dissolved carbon dioxide and bicarbonates (Wetzel, 2001). The presence of carbon dioxide in the environment, gives the opportunity to plants and phytoplankton to synthesize their food and produce oxygen, which is the basic need for all life forms. Variation in CO_2 concentration may have an adverse effect on physiological functions of the biotic lives present in aquatic ecosystem. Inorganic carbon utilization in natural water is balanced by respiratory generation of carbon dioxide by aquatic organisms and by influxes of carbon dioxide and bicarbonates with incoming surface run off and from atmosphere.

The presence of free CO_2 in the surface water is essential for photosynthesis. However, large amount of free carbon dioxide available in the ecosystem is harmful for animals as excess dissolved carbon dioxide is usually accompanied by a much reduced dissolved oxygen content and other important conditions. Besides, it regulates the pH of water which goes a long way in influencing the mode of biota and their life processes. It is well known that the carbon dioxide is the best single index of the suitability of water.

Result and Discussion:

In present investigation free CO_2 was found to be totally absent in Medical Pond during the course of study (Tables-1b, 2b, 3b). In Laldiggi Pond, the carbon dioxide was found to be absent in some months viz. September, 2009; November, 2009; December, 2009 and January, 2010. It fluctuated from a minimum of 18.0 mg/l in March, 2009 to a maximum of 30.0 mg/l in August, 2009. In Chautal Pond, it varied from a minimum of 10.0 mg/l in February, 2009 to a maximum of 45.0 mg/l in August, 2009.

The absence of free CO_2 in Medical Pond might be attributed to its utilization during photosynthesis. Moreover, phytoplankton and macrophyte combine bicarbonate to form carbon dioxide for photosynthesis and carbonates are released (Wurts and Durborow, 1992). The observations are in complete conformity with the findings of Ganapati (1960), Jana and Sarkar (1971), Jhingran, (1975), Singhal *et al.* (1986). Complete absence of CO_2 in Seikha Jheel at Aligarh was also reported by Khan and Khan (1985). On the other hand presence of CO_2 in Chautal Pond throughout the study period could be attributed to higher rates of decomposition of organic matter as the pond is more polluted. These findings are also in conformity with the findings of Sreenivasan (1972) and Singhal *et al.* (1986) who recorded CO_2 throughout the year.

The higher values of CO_2 during monsoon, post monsoon in Laldiggi Pond and Chautal Pond in present study can be related to decreased utilization and decay of organic matter and sewage inflow and addition of fecal matter through inflowing drains. Carbon dioxide also enters into the waterbody through inflowing ground water and rain water (Welch, 1952; Hutchinson, 1957).

1.9 TOTAL ALKALINITY

Introduction

The Capacity of accepting the proton ions is known as alkalinity and it measures buffering capacity of water. According to Hutchinson (1975), alkalinity is the total quantity of base that can be determined by titration with strong acid. Alkalinity of water, as usually interpreted refers to the quantity and quality of compounds present, which collectively shift the pH to the alkaline side of the neutrality (Wetzel, 1983). Though alkalinity is usually caused by the presence of hydroxides, carbonates and bicarbonates of the cations viz., Ca, Mg, Na, K, NH_4 and Fe in combined state yet it is also caused though less frequently by borates, silicates and phosphates (Wurts and Durborow, 1992). It is expressed in terms of equivalent bicarbonate or carbonate, although other ions could contribute to it. According to Jhingran (1991) total alkalinity of high range is encountered in waters having pH value ranging from 8.4 to 10.5.

Natural water bodies show a wide range of fluctuation in total alkalinity values depending upon the location, season, plankton population, rainfall, human activity and nature of bottom deposits etc. The range of alkalinity in Indian waters varied from 40 to 1000 mg/l (Jhingran, 1991). Alikunhi (1957) considered alkalinity as a measure of productivity. Spence (1964) divided south Scottish water bodies into three major categories on the basis of alkalinity viz. nutrient poor, moderately rich and nutrient rich.

The three kinds of alkalinities hydroxides (OH^-), carbonates (CO_3^{--}) and bicarbonates (HCO_3^-) can be distinguished with standard acid using phenolphthalein and methyl orange as an indicator successively.

Result and Discussion:

The monthly variations in the values of total alkalinity of water in the selected water bodies are given in Tables 1c, 2c, 3c. Total alkalinity values ranged between 145.00 mg/l and 590.00 mg/l in the selected water bodies. In Medical Pond, values of total alkalinity fluctuated from a minimum of 180.00 mg/l in March, 2009 to a maximum of 590.00 mg/l in May, 2009. Laldiggi Pond, showed the minimum value 145.00 mg/l in October, 2009 and maximum 500.00 mg/l in April, 2009. In Chautal Pond, the values varied from a minimum of 250.00 mg/l in September, 2009 to a maximum of 407.00 mg/l in November, 2009.

Variations in total alkalinity of sediment in the selected water bodies are given in Tables-1c, 2c, 3c. Total alkalinity values ranged from 64.55 mg/l to 228.00 mg/l in the selected water bodies. In Medical Pond, values of total alkalinity fluctuated from a minimum of 84.55 mg/l in November, 2009 to a maximum of 228.76 mg/l in June, 2009. In Laldiggi Pond, it showed the minimum value 73.20 mg/l in September, 2009 and maximum 201.33 mg/l in April, 2009. In Chautal Pond, the values varied from a minimum of 64.55 mg/l in November, 2009 to a maximum of 178.00 mg/l in May, 2009.

In Medical Pond alkalinity contributed by carbonates and bicarbonates throughout study period except February and March, 2009 when hydroxide and carbonate contributed. In Chautal Pond alkalinity was contributed by bicarbonates only. In Laldiggi Pond carbonates and bicarbonate alkalinity were recorded during September, November, December and January and only bicarbonate during rest of the months. Thus, carbonates, bicarbonates and hydroxides formed the basic component of alkalinity in the ponds under study. The factors responsible for higher alkalinity are entry of sewage leading to organic pollution, excessive release of soap and detergents through cloth washing with in, bathing these ponds of cattle's and decomposition of organic matter in sediment. These finding agreed with Hayes and Anthony (1959).

In present study maximum values of total alkalinity were recorded in summer which could be attributed to accelerated rate of photosynthesis leading to greater utilization of carbon dioxide and bicarbonates as source of inorganic carbon by phytoplankton and release carbonates which can cause pH to rise dramatically (Wurts and Durborow, 1992).

However, higher values of alkalinity recorded in monsoon which could be related to greater agitation of water leading to decrease in CO_2 content, leaching of carbonates and bicarbonates from catchments and organic pollution.

The observations are in agreement with the findings of Chourasia and Adoni (1985), Kumar (1990) and Khajuria (1992) but in total contrast to the observation of Jhingran (1991) and Gochhait (1991).

All these ponds with total alkalinity ranging from 150.0 mg/l to 600 mg/l can be categorized as highly productive (Alikunhi, 1957) and highly alkaline (Philipose, 1959). According to Spence (1964) higher alkalinity is always due to enrichment of ponds and lakes. He further concluded that alkalinity and pH are closely connected with an accurate measure of the trophic status of the lake water. On the basis of his assumption, all the water bodies under study are eutrophic and nutrient rich.

Statistically alkalinity showed positive correlation with Hardness in Medical Pond ($r = 0.447$) and Chautal Pond ($r = 0.365$) and negative correlation in Laldiggi Pond ($r = -0.309$) (Table- 8).

BICARBONATE ALKALINITY

Introduction:

Bicarbonate alkalinity is mostly due to presence of bicarbonate in the water and is important in the pH range of 7 to 9. Bicarbonates are of prime importance in an aquatic ecosystem and it serves as a source of inorganic carbon for the process of photosynthesis (Wetzel, 2001). Bicarbonates or half bound carbon dioxide may be regarded as sort of intermediate between fixed and free carbon dioxide. In fact it is in such a loose combination that algae are able to utilize 92% of it (Wiebe, 1931) in their photosynthesis. The total inorganic carbon concentration in freshwater depends on pH which is largely governed by the buffering reaction of carbonic acid and amount of carbonates and bicarbonates present. As a matter of fact, carbon dioxide rich water lack carbonates as former converts them into bicarbonates (Welch, 1952; Wetzel, 2001).

According to Chourasia and Adoni (1985) bicarbonate alkalinity is the main constituent to the total alkalinity. All the water bodies with a pH range of 7.0 to 9.0 always show a very high bicarbonate concentration. Seasonal variations in bicarbonate alkalinity in Indian freshwater have been studied by Ganapati (1956), Qadri and Yousuf (1980), Haque (1991), Kaushik and Sakasena (1999), Singh (2004) and Zuber (2007).

Result and Discussion:

The monthly variations in the values of bicarbonate alkalinity of these derelict water bodies are given in Tables-1a, 2a, 3a. The values of bicarbonate alkalinity varied from minimum of 20.00 mg/l to maximum of 560.00 mg/l in these selected water bodies. In Medical Pond, the values of bicarbonate alkalinity fluctuated from a minimum of 50.00 mg/l in September, 2009 to a maximum of 110.00 mg/l in May and August, 2009 and absent in February, 2009 and March, 2009. In Laldiggi Pond it showed the minimum value 20.00 mg/l in September, 2009 and maximum 560.00 mg/l in April, 2009. In Chautal Pond, it varied from a minimum of 250.00 mg/l in September, 2009 to a maximum of 407.00 mg/l in November, 2009.

The perusal of Tables-1a, 2a, 3a reveals that bicarbonate alkalinity was recorded throughout the course of study in all the ponds except Medical Pond where it was found absent in February and March, 2009. The absence of bicarbonates in Medical Pond during February and March, 2009 was due to presence of hydroxide alkalinity. This condition appears only when the phenolphthalein alkalinity is found grealer than the half of total alkalinity or twice the methyl orange alkalinity (Thereoux *et al.*, 1943).

In present study maximum value of bicarbonates were recorded during summer which could be attributed to decay and decomposition of organic matter at accelerated rate due to rise in temperature (Welch, 1952; Khajuria, 1992; Sharma, 1999; Singh, 2004; Zuber, 2007), high rates of evaporation leading to concentration and release of compounds previously locked up in mud.

The high values of bicarbonates during monsoon might be due to rains and surface run off and leaching of calcium carbonate which get converted into soluble calcium bicarbonate. The observation is in conformity with the findings of Saha *et al.* (1959), Baba (2002) and Zuber (2007).

However, low values of Bicarbonates recorded in some months in Medical Pond might be due to its utilization by algae and macrophytes.

CARBONATE ALKALINITY

Introduction:

Carbonate alkalinity shows the presence of carbonate and hydroxide in the pH range of 8.3 to 12.0. Carbonate alkalinity has inverse relationship with free carbon dioxide and it is only present when free CO_2 is absent (Theroux, 1943). Carbonates owing to their buffering capacity are of utmost importance in an aquatic environment as it tends to maintain the pH of water (Welch, 1952). Carbonates further assume significance as in colloidal and particulate forms, it tends to adsorb organic acids (Chave, 1965; Otsuki and Wetzel, 1973, 1974) in natural waters and render them available for utilization by bacteria (Wetzel, 2001). It is invariably found in all water bodies on occasions when free CO_2 is absent. It is reported to be absent in many freshwater bodies during different times (Ganapati, 1956; Sreenivasan, 1972). The main reason for its absence was found to be low photosynthetic rate of phytoplankton and green aquatic plants (Qadri and Yousuf, 1980; Yousuf and Shah, 1988).

Result and Discussion:

The monthly variations in the values of carbonate alkalinity are given in Tables-1a, 2a, 3a. The values of carbonate alkalinity ranged between 100.00 mg/l and 500.00 mg/l in the selected ponds. Medical Pond showed minimum value 100.00 mg/l in October, 2009 and maximum 500.00 mg/l in June, 2009, whereas in Laldiggi Pond, carbonate alkalinity was recorded in September, 2009, November, 2009, December, 2009 and January, 2010 only. Its values fluctuated from a minimum of 100.00 mg/l in December, 2009 to a maximum of 160.00 mg/l in January, 2010. In Chautal Pond, it was never recorded during the study period.

In present study, carbonates have been found to share an inverse relationship with free carbon dioxide. The results are in conformity with the findings of Welch (1952), Hutchinson (1957), Wetzel (1975), Khajuria (1992) and Sharma (2002). Moreover Chautal Pond is more polluted in forms of sewage, thus decomposition of organic matter, washing and bathing cattle in present study leads to the increase in CO_2 content and thus, contributes to the absence of carbonates.

1.10 TOTAL HARDNESS

Total hardness, a measure of the quality of water supplies, is governed by the content of calcium and magnesium salts largely combined with bicarbonates and carbonate (temporary hardness) and with sulphates, chlorides and other anions of mineral acids (Permanent hardness). Swingle (1967) has reported that hardness less than 5.0 mg/l gives slow growth, distress and even leads to death. Jhingran (1991) suggested that water with < 5 mg/l $CaCO_3$ is not at all suitable for fish growth.

Swingle (1967) has suggested that total hardness of 50 mg/l of $CaCO_3$ is the dividing line between soft and hard water. Sawyer (1960) has classified water into three broad categories on the basis of the range of total hardness values viz.;

i. < 75 mg/l - soft
ii. 76 – 150 mg/l - moderately hard
iii. 151-300 mg/l - hard

Andrews (1972) on the basis of the hardness of water has classified water bodies in the following manner.

i. Water having hardness from 0.0 – 60.0 mg/l as soft.
ii. Water having hardness from 61. – 120 mg/l as moderately hard
iii. Water having hardness from 121.0 - 180.0 mg/l as very hard

Unni (1982) has suggested that total hardness can be used as an indicator. The monthly variations in the values of hardness in all the selected water bodies are given in Tables-1b, 2b, 3b. The value of hardness fluctuated from a minimum of 100.0 mg/l to a maximum of 260.00 mg/l in the selected ponds. Medical Pond showed minimum value 124.00 mg/l during January, 2010 and maximum 260.00 mg/l in April, 2009. Laldiggi Pond, showed minimum hardness 112.00 mg/l in December, 2009, and maximum 170.00 mg/l in July, 2009. Chautal

Pond showed minimum values of hardness 100.00 mg/l during February, 2009 and maximum 240.00 mg/l in November, 2009.

High values of hardness were recorded the throughout study in three selected ponds. This could be attributed to high temperature, high anthropogenic activities in and around these pond and addition of sewage water from surrounding areas and use of detergents by washer men.

Rai (1974) also related high values of hardness to the inflow of sewage effluents. In present study the selected water bodies (Medical Pond, Laldiggi Pond, and Chautal Pond) ranged from moderately hard to hard water bodies (Sawyer, 1960; Andrews, 1972). On the basis of earlier work by Unni (1983), it can be concluded that high hardness is the general characteristics of water bodies situated in plains. These ponds can be regarded as most suitable and productive for the growth of fish and fisheries as they are having hardness above 15.0 mg/l, a value given by Sreenivasan (1974) and Spence (1967).

1.11 IONIC COMPOSITION

Four major anions, namely carbonates, bicarbonates, sulphate and chlorides and four major cations, namely calcium, magnesium, sodium, and potassium dominantly contribute to the ionic composition of any water body. These ions combined with each other to form compounds. Ions play a very important role in the life of aquatic flora and fauna. Ionic composition has been an index of productivity (Moyle, 1949; Sarkar and Rai, 1964).

The concentration of cations like magnesium, sodium, potassium and the major anions such as chlorides are relatively conservative and undergo only minor spatial and temporal changes within lake or pond from biotic utilization or biotically mediated environmental changes. According to Wetzel (1983), calcium, inorganic carbon and sulphate are dynamic and concentrations of these strongly influenced by microbial metabolism. According to Rhode (1949), freshwater lakes all over the world tried to maintain general rule in the content of ions (Ca > Mg >Na >K; HCO_3 >SO_4 >Cl), although regional and local peculiarities such as geological and climatic conditions counteract and conceal this tendency giving a water body different ionic composition.

A great deal of literature exists on the ionic composition of water bodies. Important contributions are those of Birge and Juday (1911), Ohle (1934), Davis (1962), Khan and Siddiqui (1974), Unni (1982), Trivedy *et al.* (1985), Gaur (1998) and Parveen (2003).

CALCIUM

Introduction:

Calcium is one of the most abundant cation of the natural waters. It is an important micronutrient which influences the growth and population dynamics of fresh water flora and fauna. Calcium is essential for the structural and functional integrity of cell membrane (Eppley, 1962; Epstein, 1965). Chlorophyllous plants utilize calcium because it is a vital micronutrient required for proper functioning in the aquatic food chain (Ovic *et al.* 2000). Distribution of certain algae has been correlated with different concentrations of calcium (Munawar, 1970; Singh and Swarup, 1979). It triggers biological productivity (Ohle, 1938). German limnologist, Ohle (1938) has given the following classification of water bodies depending upon the calcium concentration.

i. Water with Calcium < 10.0 mg/l as poor
ii. Water with Calcium 10.0 mg/l to 25.0 mg/l as medium and
iii. Water with Calcium > 25.0 mg/l as rich

On the basis of Ohle (1934) classification the water bodies under study, can be categorized as calcium 'rich' (always> 25.0 mg/l). In Indian freshwaters, calcium content fluctuated from 11.2 to 390.67 mg/l (Kaushik and Saksena, 1999).

Result and Discussion:

The monthly variations in the values of calcium content of all the three selected water bodies are given in Tables-1b, 2b, 3b. The value of calcium ranged from a minimum of 36.00 mg/l to a maximum of 89.77 mg/l in selected ponds. In Medical Pond, it fluctuated from a minimum of 36.87 mg/l in December, 2009 to a maximum of 64.12 mg/l in May, 2009. In Laldiggi Pond, it varied from a minimum of 36.00 mg/l in December, 2009 to a maximum of 89.77 mg/l in February, 2009. In Chautal Pond, it fluctuated from a minimum of 48.00 mg/l in December, 2009 to a maximum of 88.17 mg/l in March, 2009.

High values of calcium were recorded throughout the study period in all the three ponds which could be related to continuous input of sewage from surrounding areas throughout the year. However, calcium in these water bodies also appear to be of terrestrial origin being derived by weathering of calcareous materials and domestic effluents entering these ponds from adjoining colonies.

MAGNESIUM

Introduction:

Magnesium occurs in all kinds of natural water with calcium but its concentration remains generally lower than the calcium. It is required universally by chlorophyllous plants for the magnesium porphyrin complex, and a micronutrient in enzymatic transformation especially in transphosphorylation by algae, fungi and bacteria (Wetzel, 1983). The depletion of magnesium acts as a limiting factor for the growth of phytoplankton and reduces the number of phytoplankton (Kaushik and Saksena, 1999). According to Goldman (1960) little availability of magnesium has been implicated as one of the several factors influencing phytoplankton productivity in an extremely oligotrophic lake.

Magnesium is supposed to be non-toxic at the concentrations generally met in natural water. According to Kumar and Gupta (2002) decomposition process of plants and animals return magnesium to the ecosystem to be used again.

Result and Discussion:

Monthly variations in magnesium content of all the three derelict water bodies are given in Tables-1b, 2b, 3b. The value of magnesium fluctuated from a minimum of 15.82 mg/l to maximum of 43.51 mg/l in the selected ponds. In Medical Pond, it fluctuated from a minimum of 19.77 mg/l in October, 2009 to a maximum of 43.51 mg/l in May, 2009. In Laldiggi Pond, it varied from a minimum of 18.46 mg/l in January, 2010 to a maximum of 36.92 mg/l in April, 2009. In Chautal Pond, it ranged from a minimum of 15.82 mg/l in January, 2010 to a maximum of 34.28 mg/l in June, 2009.

In present study lower value of magnesium were recorded in winter which could be attributed to higher sedimentation rate leading to their settlement in the bottom, utilization by plankton organisms and its incorporation into chlorophyll. The findings are in conformity with the findings of Tripathi and Pandey (1990) and Shastree *et al.* (1991), who recorded decline in magnesium concentration during winter but in contrast with findings of Khajuria (1992), Sharma (1999) and Zuber (2007), who recorded increase in magnesium during winters. Higher concentration of magnesium during summer in present study could be related to higher rates of evaporation and decomposition of organic matter at high temperature. The present study is in agreement with the early findings of Zaffar (1964) who recorded an increase in magnesium content during summer.

CHLORIDE

Introduction:

Chlorides occur naturally in all type of waters, however, its concentration remains quite low and is generally less than that of sulphates and bicarbonates. Chloride is influential in general osmotic salinity balance and in exchange, but metabolic utilization does not cause any significant variation in the spatial and seasonal distribution within the lake (Wetzel, 1983). Lakes and ponds usually receive significant input of chloride from leaching of salts from the catchment area, organic decomposition, irrigation drainage, domestic sewage contamination.

According NEERI (1986) high concentration of chloride indicates organic pollution. In many ecosystems chloride is contributed by animal excreta (6.0 gm chloride/person/day) which raise chloride concentration in sewage. Chloride concentration 200 mg/l (WHO, 2003) is considered safe for human consumption but beyond this limit, chloride imparts salty taste to water and render it unfit for drinking purposes (Saad and Samir, 1979). According to Schmitz (1996), chlorides along with phosphate and nitrate make water eutrophic. Chlorides are highly soluble with most of the naturally occurring cations and do not precipitate and sediment and can not be removed biologically in treatment of wastes.

Result and Discussion:

The monthly variations in the values of chloride in the selected water bodies are given in Tables–1b, 2b, 3b. It ranged from 93.70 mg/l to 624.00 mg/l in the selected ponds. In Medical Pond, it fluctuated from a minimum of 127.00 mg/l in the month of January, 2010 to a maximum of 624.00 mg/l in the month of June, 2009. It ranged showed from a minimum of 93.70 mg/l in the month of December, 2009 to a maximum of 244.00 mg/l in the month of June, 2009 in Laldiggi Pond. In Chautal Pond, values fluctuated from a minimum of 135.00 mg/l in the month of February, 2009 to a maximum of 227.00 mg/l in the month of June, 2009. Statistically chloride showed positive and significant correlation with water temperature (Medical Pond: r = 0.550; Laldiggi Pond: r = 0.778; Chautal Pond: r = 0.546) (Table – 8).

In present study maximum values of chloride were recorded in summer in all the three ponds, which could be attributed to higher rate of evaporation because of high ambient temperature and maximum human activities and organic pollution of animal origin.

Kumar (1995), Kumar and Gupta (2002) and Ganai *et al.* (2010) have also recorded high chloride content during summer months and they attributed it to surface run off, loading frequently with contaminated water from the surrounding settlement and high rate of evaporation.

The observations are also in conformity with the findings of Haque (1991) who has reported maximum chloride content during summer from a polluted water body at Aligarh. However, high values of chloride content were also recorded during monsoon which could be attributed to increased concentration of organic matter presumably of animal origin washed by rains into these ponds.

Lower values of chloride content recorded in winter in present study could be attributed to reduction in siltation or allochthonous import of chloride along with rain from catchment area.

The observations are in full agreement with the findings of Sharma (1999) who recorded a decline in chloride content during winter.

Perusal of the Tables-1b, 2b, 3b, also reveals that Medical Pond has comparatively greater quantum of chloride content than that of Laldiggi and Chautal Pond. The higher concentration of chloride in Medical Pond might be due to more contamination by wastes of animal origin and greater decomposition of organic matter in these ponds.

According to Hynes (1960) increased concentration of chlorides is an indication of eutrophy caused by organic pollution. These water bodies under study are under the heavy load of organic matter as depicted by the chloride values and can be placed under eutrophic water bodies.

1.12 DISSOLVED NUTRIENTS

NITRATE NITROGEN (NO_3-N)

Introduction:

Nitrate content is an excellent parameter to judge the organic pollution and it represents the highest oxidized from the nitrogen. The nitrate is important source of nitrogen for aquatic organisms. Other forms of nitrogen in natural waters are ammonia, nitrite and organic compound, which may be utilized by some organisms in period of nitrate deficiency. All biological growth processes require nitrogen in some form or the other for synthesis of cellular protein and nucleic acids, and hence, nitrogen plays an important role in the biological productivity of aquatic ecosystem. Being responsible for the formation of chlorophyll (Rhode, 1948), nitrate is one of the most important limiting factors in the development of phytoplankton (Welch, 1952). The sources of nitrogen into inland waters are N_2-fixation, surface and ground water inflow, diffusion, transport from sediment and bottom waters, microbial magnification, animal excretion etc.

In natural aerobic waters, most nitrogen occurs as nitrates (Maitland, 1978) in varying amount depending upon the nature of water shade, seasons, degree of pollution and the abundance of Plankton (Rhode, 1969; Sommer, 1989). Excess of organic pollution leads to eutrophication. Barg (1992) opined that nitrogen pollution not only alters the water quality but also influence the primary productivity, growth of aquatic weeds, benthos, epiphytes and toxic algae. According to Mohanty (2000), a part of unutilized nitrogen is also lost into the sediments, which alters the soil nutrients status and benthic community.

Result and Discussion:

The monthly variations in the values of Nitrate-nitrogen of the selected derelict water bodies are given in Tables-1a, 2a, 3a (Fig.-32D). The values of nitrate-nitrogen ranged from a minimum of 0.051 mg/l to a maximum of 0.278 mg/l in the selected ponds. In Medical Pond, it fluctuated from a minimum of 0.054 mg/l in January, 2010 to a maximum of 0.195 mg/l in August, 2009. Laldiggi Pond showed the minimum value 0.081 mg/l in January, 2010 to a maximum of 0.195 mg/l in June, 2009. In Chautal Pond, values fluctuated from a minimum of 0.051 mg/l in January, 2010 and maximum 0.278 mg/l in September, 2009.

In present study nitrate-nitrogen recorded high concentration during monsoon and summer season. The higher value of nitrate –nitrogen during monsoon could be attributed to influx of decaying organic matter and fecal matter, contamination of pond water with sewage washed away by surface run-off into the domain of these ponds and influx of nitrate from the catchment area along with rain water (Shukla *et al.*, 1989).

Low concentration of nitrate nitrogen in present study during winter might be due to reduced rate of decomposition at low temperature and active uptake and utilization of nitrates by macrophytes (Lee *et al*, 1975).

Increased concentration of nitrate – nitrogen during summer might be due to increased rate of decomposition of organic matter at higher temperature and formation of algal mats on the surface (Sunderraj and Krishnamurthy, 1981). These observations are in agreement with the findings of Gochhait (1991).

Statistically NO_3- N recorded a significant positive correlation with water temperature (Table- 8) (Medical Pond: $r = 0.915$; Laldiggi Pond $r = 0.754$; Chautal Pond: $r = 0.686$), and with TDS in all the three selected ponds (Medical Pond: r = 0.528; Laldiggi Pond: r = 0.781; Chautal Pond: r = 0.809) (Table- 8).

PHOSPHATES-PHOSHORUS (PO_4-P)

Introduction:

Phosphorus is one of the most important nutrients of the living organisms. It is found in meteorites, rocks soil and even in the sun's atmosphere. It is much scarcer than the other principal atoms of living biota such as carbon, hydrogen, oxygen, nitrogen, and sulphur. Its abundance at the surface of the earth is about one tenth of 1 % by weight. It is taken up rapidly and concentrated by living organisms (Cole, 1979). The phosphate content in aquatic medium is considered to be nutrient of major importance in the production process (Vollenwider, 1968). The increased application of fertilizers, use of detergents and domestic sewage play a great role in contributing the heavy loading of phosphorus in the water (Golterman, 1975). Phosphates play an incredible role in biochemical pathways of respiration and carbon dioxide assimilation, being an indispensable constituent of cellular components like nucleic acids (DNA, RNA, phosphoproteins), enzymes, vitamins, nucleotide phosphates (ADP, ATP) etc. (Wetzel, 2001). Though relatively small amount of phosphates are available in hydrosphere, yet it is of considerable significance in limiting the biological productivity (Rawson, 1939; Wetzel, 2001). The increase in its concentration not only leads to pollution (Vollenweider, 1975; Wetzel, 1983) but also affects the aquatic biota (Upadhyay, 1998). Wetzel (1975) classified lakes on the basis of total phosphate content into following categories:

1.	Oligotrophic	<0.005mg/l
2.	Mesotrophic	0.005 to 0.01 mg/l
3.	Mesoeutrophic	0.01 to 0.03 mg/l
4.	Eutrophic	0.03 to 0.1 mg/l
5.	Hypereutrophic	>0.1 mg/l

Although atmospheric precipitation, geochemical condition and ground water are important sources of phosphorus, yet the major contribution to aquatic phosphate content is from agricultural and watershed run-off (Vollenweider, 1968; Cooper, 1969; Likens and Borman; 1975; Lal, 1998), fertilizers (Skaggs *et al.*, 1994; Jordan and Weller, 1996), detergents (Moss *et al.*, 1980) and domenstic sewage (Gassmann, 1994; Glindemann *et al.*, 1966).

Result and Discussion:

The monthly variations in phosphate-phosphorus in the selected ponds are given in Tables-1a, 2a, 3a (Fig.-32C). During present investigation, phosphate- phosphorus varied from 0.226 mg/l to 1.040 mg/l in the selected water bodies. In Medical Pond, it ranged from a minimum of 0.419 mg/l in March, 2009 to a maximum of 1.040 mg/l in June, 2009. Laldiggi Pond, showed minimum value 0.226 mg/l in January, 2010 and maximum 0.965 mg/l in June, 2009. In Chautal Pond, it fluctuated from a minimum of 0.240 mg/l in December, 2009 to a maximum of 0.950 mg/l in May, 2009. The water bodies under study can be classified as hypereutrophic on the basis of classification given by Wetzel (1975) as the values recorded were always greater than 0.1 mg/l.

In present study peak values of PO_4-P in the selected ponds were recorded during summer which could be related to increased decomposition rate at high temperature and greater release of nutrients there- from, higher rate of evaporation and decrease in water level leading to increase in concentration and microbial-biochemical mobilization of phosphates from particulate stores to dissolved phosphates (Stumm and Morgan, 1995). Several workers Ray and David (1966), Shukla *et al.* (1989), Gochhait (1991) and Ganai *et al.* (2010) also recorded high values of PO_4 P during summer.

Lower values of PO_4-P during winter in present study might be due to its utilization by macrophytes and algae for their growth. Besides, presence of low calcium level and low temperature could be the possible reasons as reported by Khan and Siddiqui (1974). Gochhait (1991) also recorded a decline in phosphate values during winter.

Statistically PO_4 - P recorded a significant positive correlation with water temperature in all the three selected ponds (Medical Pond: r = 0.730; Laldiggi Pond: r =0.875; Chautal Pond: r =0.739) (Table- 8). PO_4 - P recorded negative correlation with pH (Table- 8) in Laldiggi Pond (r = -0.694) and Chautal Pond (r =-0.037), whereas positive correlation in Medical Pond (r = 0.492) (Table- 8).Otsuki and Wetzel, (1973) also observed an inverse relationship between phosphate and pH.

1.13 SEDIMENT TEXTURE

It implies the percentage of sand, silt and clay present in the sediment at a given time. It influences the population and diversity of benthic organisms as well as nutrients in the sediment. The variations in the percentage composition of sand, silt and clay fractions of sediment sample at monthly intervals are given in Tables-1c, 2c, 3c (Fig.-33). The average sand content was higher in sediment in comparison of other fractions in Medical Pond and Laldiggi Pond, whereas in Chautal Pond clay composition was higher as compared to other fractions. The abundance and diversity of benthic fauna was correlated with sediment characteristics in different brackish water by several workers (Pattanaik, 1971; Harkantra, 1975; Sunil Kumar, 1995; Das *et al.*, 2001). The textural and biochemical analysis of CIB (Central Indian Basin) sediment showed considerable increase in the clay content, labial organic matters, carbohydrates and protein in 44 months (Raghukumar *et al.*, 2003). Thus the sediment analysis suggested a pragmatic improvement in the biochemical parameters and undoubtedly advocate for enhance food condition for benthos.

1.14 % ORGANIC MATTER and % ORGANIC CARBON

Introduction:

The organic content of sediments, are often considered as an important trophic source for the benthos. Animal sediment relationships are fundamental for studies on the distribution, development and maintenance of benthic communities. The grain size of sediment determines to an important degree the number of organisms within a community; therefore it functions as an environmental influence on biological diversity (Etter and Grassle, 1992). The organic contents also depend on the grain size of the sediment (Gremare *et al.*, 2002). In sediment, organic matter quality rather than quantity can be related to benthic faunal abundance (Relexans *et al.*, 1996; Fabiano and Danovaro, 1999; Danovaro *et al.*, 2000; Gremare *et al.*, 2002) and activity (Albertelli *et al.*, 1999).

The accumulation of biodeposits on the bottom under culture sites may induce organic enrichment and change sediment geochemistry and benthic community characteristics (Mattsson and Lindén, 1983; Chamberlain *et al.*, 2001; Christensen *et al.*, 2003; Callier *et al.*, 2007). According to a general model (Pearson and Rosenberg, 1978; Weston,1990), increased organic loading causes macrobenthic communities to exhibit: 1) a decrease in species richness and an increase in the total number of individuals because of high densities of a few opportunistic species, 2) a general reduction in biomass—although biomass may be greater due to dense assemblages of opportunistic species, 3) a general or species specific decrease in body size, 4) a shallowing of the portion of the sediment column occupied by infauna, and 5) a shift in the relative dominance of trophic groups.

The organic matter accumulation in any aquatic ecosystem may be autochthonous or allochthonous or both. According to Newell (1965), the organic matter present in the sediment is used by organisms as a unique source of energy and carbon for their metabolism by converting them into simple inorganic forms. They play an important role in maintaining the productivity of water body. Mackereth (1966) in the English lakes and Brunskill *et al.* (1971) in ELA lakes (Experimental lakes Area) observed that most of the organic matter derived from their drainage basin. However Gorham (1960), Gorham and Sauger (1967) and Gorham *et al.* (1979) found that the most of the organic matter was derived from primary production of lakes.

During present investigation, organic matter percentage in sediment showed variation among all the water bodies and the highest value (5.820%) was observed on clay loam substratum in Chautal Pond and lowest (0.891%) on sandy clay loam substratum in Medical Pond. The organic matter in sediment of Medical Pond varied from 0.891% during May, 2009 to 3.914% during September, 2009, In Laldiggi Pond it ranged from 1.321% during January, 2010 and 4.290% during October, 2009, whereas in Chautal Pond the value fluctuated between 1.098% during March, 2009 and 5.820% during November, 2009 given in Tables-1c, 2c, 3 c (Fig.-32B). Mehrotra (1988) recorded organic matter from Lal Sagar reservoir (11.4 mg/g to 30.4 mg/g) and Singhal (1986) from Takhat Sagar (2.8 mg/g to 33.0 mg/g) from the littoral zones of their respective water bodies.

Hendrick and Silvey (1973) observed poor range of organic matter (1.1 mg/g) in the sediment of Ganza little Elm reservoir, however, very high (46 to 350 mg/g) organic matter content were reported from 16 Wincinsin lakes. Wiliam *et al.* (1971) also observed high organic matter (63 to 86 mg/g) in Klamath lake. According to Dermott *et al.* (1986), the high organic matter content of the lake sediment may be partly due to an increased percentage of refractory debris from terrestrial source.

Sinking particulate organic matter serves as a high quality food source for many forms of marine life, including benthic sedimentary communities (Gray, 1981; Widbom and Frithsen, 1995; Parrish, 1998). Food supply is therefore a potentially important structuring mechanism for benthic communities that has gained some attention (Josefson and Conley, 1997; Galeron *et al.*, 2000), but surprisingly, has been addressed by only a small number of studies till date. The significance of food supply for macrobenthic communities is far from well understood, in part because their effects vary widely among habitats, depths, and locations (Grebmeier *et al.*, 1988; Gould and Gallagher, 1990; Ambrose and Renaud, 1997; Stocks and Grassle, 2001). In fact, the organic matter that the benthos receives can have very different effects depending on concentration and timing of delivery (Widbom and Frithsen, 1995; Widdicombe and Austen, 2001). Too much organic matter can have an adverse effect on benthic communities, as described in classic models of anthropogenic organic enrichment (Pearson and Rosenberg, 1978). For example, there is already strong evidence that large organic loads combined with low physical disturbance yield lower than expected diversities (Widdicombe and Austen, 2001). Similarly, numerous eutrophication studies consistently show that high levels of organic enrichment, carbon or other nutrients such as nitrogen or phosphorous generally lead to increase in a few opportunistic species, while decreasing diversity and abundance of other less opportunistic species (Oviatt *et al.*, 1986; Widbom and Frithsen, 1995; Gray *et al.*, 2002). Statistically organic matter recorded negative correlation with benthic fauna in all the three selected ponds (Medical Pond: $r = -0.198$; Laldiggi Pond: $r = -0.586$ and in Chautal Pond: $r = -0.343$).

During present investigation, organic carbon percentage in sediment varied from 0.516% to 3.375%. In Medical Pond it varied from 0.516% during May, 2009 to 2.270% during September, 2009, In Laldiggi Pond it ranged from 0.766% during January, 2010 and 2.488% during October, 2009, whereas in Chautal Pond the value varies between 0.636% during March, 2009 and 3.375% during November, 2009 (Tables-1c, 2c, 3 c; Fig.-32A).

Part 2

Benthic species composition, abundance and diversity

2. BENTHIC SPECIES COMPOSITION, ABUNDANCE AND DIVERSITY

Benthic communities are especially useful in detecting and evaluating the impacts of low dissolved oxygen events and aquatic contamination because exposure to anoxia/hypoxia is greatest in near bottom waters and hydrophobic anthropogenic contaminants typically accumulate in sediments. Benthic organisms with limited mobility cannot avoid adverse conditions and better reflect local environmental conditions compared to most pelagic fauna (Gray, 1979). The diversity of physiological tolerances, life history strategies, feeding modes, and trophic interactions can make sedimentary benthic communities effective estimators of environmental condition. Several papers concern the use of benthic indices to assess the ecological quality, status of marine and estuarine environments (Blanchet *et al.*, 2008; Borja *et al.*, 2008; Dauer *et al.*, 2008; Puente *et al.*, 2008; Teixeira *et al.*, 2008; Weisberg *et al.*, 2008). These papers underline the development of ecological assessment for soft-bottom benthic communities, especially in the estuarine environment.

In lakes or ponds bottom, dead and decaying organic matter from higher up in the water column which drifts down to the depths serves as source of energy. This dead and decaying matter sustains the benthic food chain. However, most organisms in the benthic zone are scavengers or detritivores. The main food sources for the benthos are algae and organic runoff from land. The depth of water, temperature and salinity, and type of local substrate all affect what benthos is present. In waters light reaches the bottom, benthic photosynthesizing diatoms can proliferate. Filter feeders, such as sponges and bivalves, dominate hard, sandy bottoms. Deposit feeders, such as polychaetes, populate softer bottoms, where Fish, snails, cephalopods, and crustaceans are important predators and scavengers.

Meiofauna has been subject for intense quantitative study due to the important role it plays in the marine food chain. Earlier short term studies have yielded clear ecological inferences on spatial variability, dominance and vertical distribution. However, the occurrence of temporal pattern, seasonality and the predominance has rarely been demonstrated in the tropical fresh waters.

Macrobenthos as polychaete worms, bivalves, turbellarians and crustaceans and insects and meiobenthos such as nematodes, foraminiferans, water bears, gastrotriches and smaller crustaceans such as cladocera, copepods and ostracodes have specific requirements in terms of physical and chemical conditions. Changes in presence/absence, numbers, morphology, physiology or behaviour of benthic organisms can indicate that the physical and/or chemical conditions are outside their preferred limits (Rosenberg and Resh, 1993). Presence of numerous families of highly tolerant organisms usually indicates poor water quality (Hynes, 1998). Benthic macroinvertebrates are moderately long-lived and are in constant contact with water sediments. Contamination and toxicity of sediments will therefore affect those benthic organisms which are sensitive to them. Acidification of lakes is accompanied by shifts in the composition of benthic assemblages to dominance by species tolerant of acidic conditions. Effects of rapid sedimentation are less well-known but appear to cause shifts toward lower abundances and oligotrophic species assemblages as well as more motile species. The profundal habitat, in the hypolimnion of stratified lakes, is more homogeneous due to a lack of habitat and food heterogeneity, and hypoxia and anoxia in moderately to highly productive lakes are common. The profundal habitat is usually dominated by three main groups of benthic organisms including chironomid larvae, oligochaete worms, and phantom midge larvae (Chaoborus). Many species of chironomids and tubificid oligochaetes are tolerant to low dissolved oxygen, such that these become the dominant profundal invertebrates in lakes with hypoxic hypolimnion. As hypoxia becomes more severe tubificids can become dominant over chironomids. In cases of prolonged anoxia, the profundal assemblage might disappear entirely.

Interannual variability of benthic communities is high because of the many physical, chemical, and biotic factors that impinge on these communities. For example, weather, nutrient supply, and interspecific interactions all serve to regulate the benthos seasonal variability of community structure and productivity because many species of benthic macroinvertebrates have annual (or shorter) life cycles, which culminate in an adult phase during the open-water period. Thus, the presence of mature larvae, pupae, or adults (the life stages most useful for taxonomic work) may be short-lived and easily missed.

The most diverse group of freshwater benthic macroinvertebrates is the aquatic insects, which account for ~70% of known species of major groups of aquatic macroinvertebrates in North America (Thorp and Covich, 1991). More than 4000 species of aquatic insects and water mites have been reported from Canada (Danks and Rosenberg, 1987). Thus, as a highly diverse group, benthic macroinvertebrates are excellent candidates for studies of changes in biodiversity. Aquatic insects often make good indicators because they are present in some capacity in almost every type of habitat and many are habitat specialists (Lewis and Gripenberg, 2008). Considerable information is available on aquatic insect in response to variety of environmental conditions. Thus, they are used as valuable indicators of ecological conditions (Baumann, 1979). Moreover, they are good indicators of localized conditions because unlike fish, they do not migrate appreciably. They integrate effects of short - term environmental variations more effectively than do algae because they usually have much larger life cycles. Degraded conditions can be detected by experienced biologists, with cursory examinations because of ease in identification to family or lower taxonomical levels. Among benthos, insects are more abundant and most of the streams, lakes and ponds, permitting computation of statistically reliable results. Healthy aquatic environments have a lot of different sensitive kinds, while polluted environments have only a few kinds of tolerant aquatic insects. In addition, sampling of aquatic insects has minimal detrimental effects on the resident biota.

Benthos, especially the aquatic insects is also used in bio-assay work, commonly used to ascertain effects on non target aquatic insect species, and thus have a direct relationship to environmental protection. Physico-chemical feature of water (Das and Bishat, 1979) and ecological factors such as eutrophication and pollution, quality and quantity, of aquatic vegetation, texture of lake substratum (Pandit *et al.*, 1991) have been shown to affect distribution and relative abundance of aquatic insects including benthic forms of bugs and beetles in cold water Kumoun lakes in India.

Aquatic insects particularly members of the order Ephemeroptera, Plecoptera, Tricoptera and Diptera (Dudgeon, 1999) are among the mostly commonly chosen groups of bio-indicators used in environmental assessment because they provide more accurate information about the changing conditions than chemical and microbiological data, which gives short term fluctuations (Persoone and De Pauw, 1979). The abundance of Ephemeroptera, Plecoptera, Trichoptera and Chironomidae indicates the balance of the community, since Ephemeroptera, Plecoptera, Trichoptera are considered to be more sensitive and Chironomidae less sensitive to environmental stress (Plafkin *et al.*, 1989). A community considered to be in good biotic condition will display an even distribution among these four groups, while communities with disproportionately high numbers of Chironomidae may indicate environmental stress (Plafkin *et al.*, 1989). Reasons for the apparent popularity of aquatic insects in current bio-monitoring practice are that they are ubiquitous, species rich, long lived and their ability to integrate temporal condition. According to Campbell (1939), Hynes (1960), Olive (1976) nymphs and larvae of stoneflies, mayflies and caddisflies are integral components of the benthic fauna of the most relatively undisturbed streams.

2.1 CLADOCERA

Introduction:

The benthic Cladocera comprise a suite of species that occupy various littoral and profundal habitats. In Lake Myvatn, Iceland, which is renowned for its abundance of wildlife, a large proportion of the secondary production is channeled through the zoobenthos where chironomids play a major role and Cladocera are prominent (Jónasson 1979). The largest Cladocera species there, *Eurycercus lamellatus* (Müller), serves as food for certain duck species (Gardarsson 1979; Gardarsson and Einarsson 2002) and the Arctic Charr *Salvelinus alpinus* (L.), the main commercial fish in the lake. Since 1990 density of benthic Cladocera has been monitored with activity traps (Örnólfsdóttir and Einarsson 2004).

Cladocera forms an important component in most lake ecosystems and have been studied extensively. The life history and population dynamics of Cladocera were studied by Lynch (1980 a) and Grover *et al.* (2000) and their response to factors like nutrient loading and the predatory environment was studied by Jeppesen *et al.* (1998). The Cladocera can themselves induce changes in the lake ecosystem: as their populations vary, so does the grazing pressure on small phytoplankton with resulting changes in water transparency (Christoffersen *et al.*, 1993). Although the causal pathways are not always clear, manipulation of planktonic Cladocera through suppressed fish predation has become a potential tool for lake management ("biomanipulation") (Gulati *et al.*, 1990; Jeppesen *et al.*, 1996). The shift can be seen as a lake-wide change in the size structure of the benthic community. The benthic cladocerans were studied by Adalsteinsson (1979) and Örnólfsdóttir and Einarsson (2004) and a palaeolimnological record of the Cladocera was presented by Einarsson and Haflidason (1988) and Einarsson *et al.* (2002). Romanovsky and Feniova (1985) proposed a hypothesis, backed up by simulations and laboratory experiments with Cladocera, which implies that when the food situation is poor and stable, small species out compete the juvenile stages of the larger species, and thus become dominant. The species with the lowest food level threshold for reproduction will be the best competitors under these food conditions (Lampert and Schober, 1980; Lynch, 1980b). It is still unknown to what extent the size efficiency and food density thresholds observed or postulated in the pelagic species apply to the littoral chydorids. Experiments conducted by Fryer (1968) suggest that chydorid Cladocera species differ in their ability to utilize the available food resources.

Based on traditional morphological analysis, cladocera is regarded as an artificial group representing four orders of Branchiopoda, namely Ctenopoda, Anomopoda, Onychopoda and Haplopoda (Korovehinsky, 2000). This group is even incorporated in different sub classes of crustacea (Starobogator, 1986; Fryer, 1987). The importance of cladocera in the trophic dynamics of freshwater systems, being the main component of benthos, has long been recognized (Sinha and Khan, 1998). They are the consumers of first order, directly drawing energy from primary producers of the ecosystem viz. phytoplankton. A large proportion of the secondary production is channeled through the zoobenthos where chironomids play a major role and Cladocera are prominent (Jónasson, 1979).

They form the food for planktivorous fishes and other invertebrates, transferring energy to higher trophic levels. Besides, they have also been reported to be reliable indicator of eutrophic nature of water bodies (Sinha and Khan, 1998; Sharma, 2001). The cladoceran in general and the representatives of the largest family Chydoridae in particular are considered to be excellent guide forms in paleo-limnological endeavors and help in resurrecting the trophic history of ancient lakes and reservoirs (Sharma, 2001). They serve as major prey item for many species of invertebrates and vertebrates and invariably comprise food of fry, fingerlings and adults of many economically important and cultivable species of fishes. Their status was lastly reviewed by Sharma and Michael (1987) and Sharma (1991, 2001). Gulati (1978) stated that if the food supply is high or increasing for a stretch of time, cladocerans usually level up high in number and biomass to dominate Lake Benthos. Chourasia and Adoni (1985) stated that the decline in the number of cladocerans in the presence of sufficient food might be due to fish predation and competition for food between cladocerans and other benthos groups. Benthic Cladocera have been shown to modify their environment (Van de Bund and Davids, 1993).

Significant work have been done on these organisms in the past by Khan and Siddiqui (1974), Smirnov (1976), Pennak (1978), Chiang and Du (1979), Wetzel (1983), Fernando and Kanduru (1984), Khan *et al.* (1986), Sharma and Michael (1987), Michael and Sharma (1988), Sharma and Sharma (1990), Sharma (1991; 2001), Tifnuati *et al.* (1994), Olesan (1998), Sinha and Khan (1998) and Negra *et al.* (1999).

Result and Discussion:

Cladocera formed the third abundant group in Medical Pond and Laldiggi Pond whereas second in Chautal Pond. The monthly variations in density of various taxa of Cladocera (No/m^2) in the selected water bodies are given in Tables-4, 5, 6. The population density of Cladocera ranged from a minimum of

278 No/m^2 during July, 2009 to a maximum of 632 No/m^2 in December, 2009 in Medical Pond, from 374 No/m^2 during October, 2009 to 834 No/m^2 in January, 2010 in Laldiggi Pond and from 329 No/m^2 during August, 2009 to 908 No/m^2 in January, 2010 in Chautal Pond. Total percent contribution of Cladocera was found to be ranged from 8.06 % during January, 2010 to 14.74 % in December, 2009 in Medical Pond, from 12.75 % during September, 2009 to 18.83 % in May, 2009 in Laldiggi Pond and from 10.49 % during August, 2009 to 22.63 % in April, 2009 in Chautal Pond.

Statistically Cladocera recorded significant negative correlation with water temperature (Medical Pond: $r = -0.610$; Laldiggi Pond: $r = -0.647$; Chautal Pond: $r = -0.503$), whereas, it showed significant positive correlation with D.O. in all the three selected ponds (Medical Pond: $r = 0.698$; Laldiggi Pond: $r = 0.854$; Chautal Pond: $r = 0.627$) (Table- 8). A negative significant correlation was obtained with T.D.S in Medical Pond ($r = -0.622$) and in Laldiggi Pond ($r = -0.604$) and insignificant in Chautal Pond ($r = -0.298$) and with diversity index, it showed positive correlation in Medical Pond ($r = 0.464$) and Laldiggi Pond ($r = 0.259$) and negative in Chautal Pond ($r = -0.542$) and Correlation between benthic species Diversity and Cladocera density showed insignificant positive correlation in Medical Pond ($r = 0.464$) and Laldiggi Pond ($r = 0.259$) and significant negative in Chautal Pond ($r = - 0.542$) (Table- 8).

Maximum Cladocera density during winter was reported by Khan and Siddiqui (1978), whereas Khan *et al.* (1986) have reported higher numerical strength of cladocera during summer. It is well known that owing to their size and relatively high intrinsic rates of population increase, cladocerans are the most important benthos component in fresh water in its functional role of phytoplankton grazing. Cladocerans are herbivorous plankton feeders and feed mainly on algae. Moreover, in the smallest size cases, detritus and bacteria are utilized as food along with algae (Tifnuoti *et al.,* 1994).

Benthic cladocera distribution and abundance in these ponds have showed wide fluctuations in response to favorable and unfavorable conditions. The littoral and limnetic cladocerans contribute significantly to biological productivity and energy flow in freshwater environs because of their rapid turnover rates and capability to build up substantial populations within short periods of time. Presence of detritus of all kinds, bacteria, algae and protozoans are important for their abundance as all these form the bulk of the ingested material of benthos (Pennak, 1978).

***Daphnia pulex*:** Anterior margin of head is broadly rounded, sometimes almost a straight line, normal to body axis, in lateral view (Edmondson, 1959) (PLATE-II). In Medical Pond its minimum density (63 No/m^2) was noted during June, 2009, whereas maximum density (193 No/m^2) was noted during December, 2009. In Laldiggi Pond, it showed minimum density (125 No/m^2) during May, 2009 and maximum density (327 No/m^2) during August, 2009 and in Chautal Pond its minimum density (115 No/m^2) during March, 2009 and maximum density (312 No/m^2) during December, 2009.

***Bosmina* sp.:** Antennules are almost parallel to each other, curving backward. Post abdomen is almost quadrate, anus is terminal, oral denticles small and inconspicuous (Sharma, 2001) (PLATE- II). In Medical Pond its density ranged from 61 to 253 No/m^2 during May, 2009 and December, 2009 respectively, whereas in Laldiggi Pond from 72 to 217 No/m^2 during March, 2009 and January, 2010. In Chautal Pond, its density was higher as compared to Medical Pond and Laldiggi Pond, ranging from 125 to 314 No/m^2 during August, 2009 and June, 2009 respectively (Tables- 4, 5, 6).

***Moina* sp.:** Body is thick and heavy, antennules large, movable and arising from flat ventral surface of head. It is commonly found in muddy pools and eutrophic ponds (Sharma, 2001) (PLATE- II). In Medical Pond its density ranged from 93 to 329 No/m^2 in January, 2010 and March, 2009. In Laldiggi Pond it ranged from 74 to 412 No/m^2 in October, 2009 and January, 2010, whereas in Chautal Pond, it ranged from 75 to 338 No/m^2 during August, 2009 and December, 2009 (Tables- 4, 5, 6).

2.2 COPEPODA

Introduction:

Copepods are very ancient arthropods and the diminutive relatives of crabs and shrimps. In terms of their size diversity and abundance they are often called "water fleas" (Reddy, 2001). They inhabit many of the habitats such as lakes, reservoirs, wetlands, tanks, ponds and pools (Tonapi, 1980). Free living copepods are separable into three distinct groups, the Calanoida, Cyclopoida and Harpacticoida (Wetzel, 1983). Members of the families Cyclopidae in the Cyclopoida and Diaptomidae in the Calanoida are highly successful in the freshwaters and mostly represent the Indian planktonic copepods (Reddy, 2001). Till now, over 10,000 copepod species are known including thousands of free living species with highly varying body shapes and a large number of parasitic and semi parasitic forms with extremely reduced morphology (Reddy, 2001) .

Harpacticoid copepods numerically dominate emerging fauna in most habitats (Cahoon and Tronzo, 1988; Walters, 1988; Armonies, 1989) and a significant proportion of sediment-dwelling copepod assemblages frequently enter the water column (Walters and Bell, 1986; Walters, 1991). Copepod emergence is influenced by ambient light levels (Armonies, 1988a), tidal (Bell et *al.*, 1988) or diurnal periods (Walters 1988, 1991), current velocities (Armonies, 1988b), copepod densities (Service and Bell, 1987; Walters, 1991) and species behaviors (Walters, 1991).

Possible reasons for harpacticoid copepods emerging from the sediment include mating (Bell *et al.*, 1988), foraging sal (Kurdziel and Bell, 1992). Separate studies of copepod advention and the colonization of defaunated sediments in hydrodynamically active habitats (Sherman and Coull, 1980; Chandler and Fleeger, 1983; Kern and Taghon, 1986; Fegley, 1988) suggest a direct connection between pelagic dispersal and benthic recruitment. In unvegetated habitats a few studies have documented the simultaneous emergence and resettlement of copepods (Cahoon and Tronzo, 1988; Jacoby and Greenwood, 1988, 1989).

In other words, copepods can make organic material available to higher trophic levels in a larger pellet form thus saving the foraging energy of their predators.

Some cyclopoids, such as *Microcylops, Megacyclops and Mesocyclops* can be used as biological agents in mosquito control and *Paracyclops* to control plant parasitic nematodes (Reddy, 2001). Copepods can be directly collected in appreciable quantities from nature or cultivated on mass scale and offered as live food to fish larvae in commercial aquaculture practices. Economically, there may also be negative effects exercised by copepods. For example, as parasites, they can at times cause serious losses to fisheries and aquaculture (Reddy, 2001). It is well known that cyclopoids, mostly *Mesocylops spp.*, act as vectors of human parasites of which the most important one is the guinea worm, *Dracunculus medinensis*, causing Dracunculosis (Reddy, 2001). Copepods are known as significant chitin producers in planktonic and benthic ecosystems (Reddy, 2001). They are primary and secondary consumer in aquatic chain. The food of Copepods consists mostly of unicellular plants and animals, small metazoans, as well as organic debris, and it has now been well established that debris may, under some circumstances, form the majority of material ingested (Pennak, 1978). Cannibalism on immature stages is common in this group of animals (Pennak, 1978).

Vast literature exists on the diversity of copepods like those of Rajendran (1973), Mamaril and Fernando (1978), Fernando (1980), Swar and Fernando (1980), Dussert and Fernando (1985), Hazarika and Dutta (1988), Reddy (1994, 2001), Nayer *et al.* (1999), Pathak and Mudgal (2002), Prakash *et al.* (2002), Sharma and Lynghdoh (2003), Sharma and Lyngoskar (2003), Jeelani *et al.* (2004), Surkad (2004), Menzar *et al.* (2005), Rao *et al.* (2006), Ansari *et al.* (2007 a) etc.

Result and Discussion:

Copepods formed seventh abundant group in Medical Pond; fourth in Laldiggi Pond and eighth in Chautal Pond. Copepods were represented by two genera *Cyclops viridis* and *Diaptomus sp.* The population density of Copepods ranged from a minimum of 154 No/m^2 during September, 2009 to a maximum of 403 No/m^2 in January, 2010 in Medical Pond, from 189 No/m^2 during August, 2009 to 662 No/m^2 in January, 2010 in Laldiggi Pond and from 111

No/m^2 during March, 2009 to 314 No/m ^{2} in January, 2010 in Chautal Pond Tables-4, 5, 6. Total percent contribution of copepods ranged from 5.11 % during December, 2009 to 9.67 % in January, 2010 in Medical Pond, from 5.16 % during August, 2009 to 14.70 % in May, 2009 in Laldiggi Pond and from 2.82 % during June, 2009 to 7.39 % in October, 2009 in Chautal Pond. Statistically Copepoda recorded significant negative correlation with water temperature (Medical Pond: $r = -0.675$; Laldiggi Pond: $r = -0.543$; Chautal Pond: $r = -0.745$; Table – 8; Fig.5), whereas, it showed significant positive correlation with D.O. (Medical Pond: $r = 0.523$; Laldiggi Pond: $r = 0.662$; Chautal Pond: $r = 0.817$) and insignificant negative correlation with TDS (Medical Pond: $r = -0.306$; Laldiggi Pond: $r = -0.473$; Chautal Pond: $r = -0.292$) in three selected pond. With diversity index, it showed insignificant negative correlation in Medical Pond ($r = -0.267$) and Chautal Pond ($r = -0.126$), whereas insignificant positive in Laldiggi Pond ($r = 0.213$). Correlation between benthic species Diversity and Copepoda density showed insignificant negative correlation in Medical Pond ($r = -0.267$) and Chautal Pond ($r = -0.126$) whereas insignificant positive correlation in Laldiggi Pond ($r = 0.213$) (Table- 8).

Seasonal variations in this group have been reported by Patil and Goudar (1985) and Kaushik and Sharma (1994). According to Chen (1965), seasonal changes in temperature cause the seasonal fluctuations in copepods. Among the representative species of copepods, *Cyclops viridis* dominated the group in all ponds.

Copepods have been reported to be good indicators of water quality (Khan and Rao, 1981; Mahajan, 1981). According to Swar and Fernando (1980) physicochemical qualities of water are the major influencing factors for the variation in the diversity of benthos organisms. Availability of the food increases the number of copepods by increasing the production of their nauplii larvae (Mathew, 1985).

Although copepods exist under a wide range of environmental conditions, yet many species are limited by temperature, dissolved oxygen and other physicochemical factors (Mahajan, 1981). During the present investigations, the occurrence of egg bearing females, nauplii and copepodite stages was found in almost all the months of the investigation period. This indicates their continuous breeding behaviour without being affected by prevailing environmental conditions.

Cyclops viridis: Caudal setae are four in number and unequal in length. Innermost terminal caudal setae much longer than ramus (Edmondson, 1959). Its Furcal rami are with thickened ridge on dorsal side and P5 first segment is not expanded laterally (Sharma, 2001) (PLATE III). Its minimum density 63 No/m^2 during July, 2009 and maximum density 239 No/m^2 during January, 2010 were recorded in Medical Pond. In Laldiggi Pond, it was higher in density as compared to other pond and showed minimum 105 No/m^2 in June, 2009 and maximum 314 No/m^2 January, 2010. In Chautal Pond it recorded minimum 54 No/m^2 during April, 2009 and maximum 186 No/m^2 during January, 2010 (Tables- 4, 5, 6).

Diaptomus sp.: Terminal caudal setae are four in number and more or less equal in length (Edmondson, 1959) (Plate III). The monthly variation in *Diaptomus* population (No/m^2) in the selected water bodies is given in Tables-4, 5, 6. The population density of *Diaptomus* ranged from a minimum of 61 No/m^2 during September, 2009 to a maximum of 164 No/m^2 in January, 2010 in Medical Pond, from 64 No/m^2 during August, 2009 to 348 No/m^2 in January, 2010 in Laldiggi Pond and from 38 No/m^2 during July, 2009 to 152 No/m^2 in October, 2009 in Chautal Pond.

2.3 ROTIFERA

Introduction:

Rotifera, one of the oldest groups and a minor phylum of invertebrates, include animals commonly termed as "Wheel Animalcules" because of their characteristic "wheel organ" or "corona" (Sharma, 2001). Rotifers are the most important soft bodied invertebrates in the fresh water plankton and benthos and characteristically inhabitants of inland waters (Hutchinson, 1967). Further, the members of this group are known to exhibit worldwide occurrence from the

Arctic and Antarctic regions to the tropics. The rotifers occur in an endless variety of aquatic and semi aquatic habitats, including limnetic and deepest regions of the largest lakes and smallest puddles. They are found in damp soil and vegetable debris, in mosses that may be netted or dampened only occasionally (Pennak, 1978). About 95% of the known rotifer species, belonging to superclass Eurotatoria, inhabit freshwaters (Sharma, 2001) except two genera and few species which are marine (Wetzel, 1983).

They were originally treated as Infusoria due to their conspicuous ciliation and microscopic size and, hence, were not distinguished from unicellular organisms. The terms "Rotifera" or "Rotatoria" had long been invariably used for this primitive group; their nomenclature status was first questioned and reviewed (Ricci, 1983) at international symposium held at Uppsala, Sweden in 1982 and the former term was accepted to be valid by the rotiferologists for all future applications. Rotifers exhibit high population turnover rate in nature and therefore, respond more quickly to environmental changes than any other group of aquatic organisms. About three-quarters of the rotifers are sessile and associated with littoral substrates. They also act as valuable indicators of trophic conditions of water (Sladecek, 1983). Locomotion through water is mostly dependent on the peripheral cilia. Many plankton and limnetic species remain in permanent suspension without ever coming in contact with a substrate. Such locomotion is often a combination of twisting on the longitudinal axis and spiral movements of the whole animal. A few plankton genera, such as *Filinia*, *Hexarthra* and *Polyarthra* move by sudden jerks and leaps, owing to sudden beating movements of their long appendages (Pennak, 1978). Various investigators have designated certain species as monocyclic, dicyclic or acyclic and perennial, according to whether their annual population curves have one, two, several or no pronounced peaks. *Brachionus angularis* and *Keratalla cochlearis* are often considered dicyclic with spring and autumn maxima, but are sometimes perennial (Pennak, 1978). *Polyarthra* is dicyclic, polycyclic or perennial (Pennak, 1978). *Keratella quadrata* may be most abundant in spring or autumn, or it may be perennial (Pennak, 1978). *Asplanchna priodonta* is variously considered monocyclic, dicyclic or perennial (Pennak, 1978). Some of the common genera, like *Asplanchna, Pleosoma,* *Synchaeta* and *Trichocerca* feed on other rotifers and all kinds of small metazoan, either in the plankton or on a substrate. The great majority of species are omnivorous and ingests all organic particles of the appropriate size. Common examples are *Cephalodella, Filinia, Keratella, Lecane, Euchlanis, Epiphanes and Brachionus.*

Important publications related to rotifers are those of Donner (1965), Ruttner-Kolisko (1974), Pontin (1978), Pennak (1978), Sladecek (1983), Wallace and Snell (1991), Sharma (1991, 1995, 1996, 1998, 2000, 2001), De Smet (1995, 1996), De Smet and Purriot (1996) and Melone *et al.* (1998), Deneke (2000) Weithoff (2004, 2005), Obertegger, *et al.* (2008), Wacker and Weithoff (2009), Hartwich *et al.* (2010).

Result and Discussion:

Rotifera formed the first most abundant group of benthic fauna in all the three selected water bodies. This group was represented by six genera viz *Brachionus, Keratella, Notholca, Filinia, Hexarthra, and Asplanchna.* The monthly variations in density of various genera of Rotifers (No/m^2) in the selected water bodies are given in Tables-4, 5, 6. The population density of Rotifers ranged from a minimum of 723 No/m^2 during July, 2009 to a maximum of 1282 No/m^2 in January, 2010 in Medical Pond, from 776 No/m^2 during May, 2009 to 1313 No/m^2 in January, 2010 in Laldiggi Pond and from 749 No/m^2 during September, 2009 to 1727 No/m^2 in January, 2010 in Chautal Pond. Total percent contribution of Rotifers ranged from 23.47 % during December, 2009 to 35.12 % during September, 2009 in Medical Pond, from 22.31 % during January, 2010 to 33.73 % in August, 2009 in Laldiggi Pond and from 24.83 % during September, 2009 to 41.45 % in March, 2009 in Chautal Pond.

Statistically Rotifera recorded a significant negative correlation with water temperature (Medical Pond: $r = -0.769$; Laldiggi Pond: $r = -0.618$; Chautal Pond: $r = -0.584$- Table- 8, Fig.-6), whereas with D.O., it showed significant positive correlation in all the three selected ponds (Medical Pond: $r = 0.599$; Laldiggi

Pond: r = 0.631; Chautal Pond: r = 0.566). It showed negative correlation with TDS in all the ponds (Medical Pond: r = -0.171; Laldiggi Pond: r = -0.646; Chautal Pond: r = -0.782) and with diversity index in Medical Pond (r = -0.172) and Chautal Pond (r = -0.623), whereas positive in Laldiggi Pond (r = 0.243). Correlation between benthic species Diversity and Rotifers density showed insignificant in all ponds except Chautal Pond where it was insignificant negative (Medical Pond: r = - 0.172; Laldiggi Pond: r = 0.243 and in Chautal Pond: r = - 0.623) (Table- 8).

Among the common and widely distributed species of *Brachionus*, *B. calyciflorus*, *B. bidentatus* and *B. angularis* are common species in Indian waters. Species of *Keratella, Notholca,* and *Brachionus*, are semi-planktonic in nature. Whereas *Polyarthra, Hexarthra, Conochilus, Filinia* and *Asplanchna* are planktonic or semi-planktonic in nature (Sharma, 2001). They depict cyclomorphosis and exhibit different ecotypes (Khan and Alam, 1999). They have been designated as indicator of organic pollution in eutrophic water bodies (Sharma, 2001).

***Brachionus calyciflorus*:** Anterior occipital margin with four broad based spines, median occipital spines distinctly longer than laterals, (Sharma, 1998 a) (Plate- I). It was low in density in Medical Pond as compared to Laldiggi Pond and Chautal Pond. In Medical Pond, densities varied from minimum 45 No/m^2 during August, 2009 to maximum 212 No/m^2 during March, 2009 (Table-4). In Laldiggi Pond, it showed minimum density 115 No/m^2 in October, 2009 and maximum 418 No/m^2 in February, 2009 (Table-5). In Chautal Pond, it was found minimum 57 No/m^2 during September, 2009 and maximum 516 No/m^2 in January, 2010 (Table- 6).

***Brachionus bidentata*:** Anterior margin with occipital spines, lateral and medians longer than intermediate occipital spines (Sharma, 1998 a) (Plate- I). Its population density varied from a minimum of 84 No/m^2 in March, 2009 to a maximum of 226 No/m^2 in December, 2009 in Medical Pond, from 25 No/m^2 in August, 2009 to 219 No/m^2 in February, 2009 in Laldiggi Pond and from 63

No/m^2 in May, 2009 to 519 No/m^2 in January, 2010 in Chautal Pond (Tables-4, 5, 6) (PLATE I).

Brachionus angularis: Anterior margin is with two median occipital spines. Posterior spines lacking (Sharma, 1998 a) (Plate- I). Its density varied from a minimum of 84 No/m^2 in September, 2009 to a maximum of 312 No/m^2 in April, 2009 in Medical Pond, from 27 No/m^2 September, 2009 to 175 No/m^2 in April, 2009 in Laldiggi Pond and from 86 No/m^2 in July, 2009 to 326 No/m^2 December, 2009 in Chautal Pond (Tables- 4, 5, 6).

Keratella tropica: Six anterior occipital spines are present, median occipital spines are longest, pointed and out curved; Posterior spines unequal and variable in length, the right spine generally longer than the left, the left posterior spine much reduced in some specimen (Sharma, 1998 a) (Plate- I). In Medical Pond, its density was found to vary between 27 No/m^2 during month of August, 2009 and 175 No/m^2 2009 during November, 2009 (Table-4). In Laldiggi Pond, it varied between 27 No/m^2 during June, 2009 and 177 No/m^2 during March, 2009 (Table-5), whereas in Chautal Pond between 54 No/m^2 in October, 2009 and 219 No/m^2 in December, 2009 (Table-6).

Keratella quadrata: Six anterior occipital spines are present, median spines longest and curved (Sharma, 1998 a) (Plate- I). It showed low density in Medical Pond as compared to Laldiggi Pond and Chautal Pond. In Medical Pond it showed variations between 24 No/m^2 in August, 2009 and 115 No/m^2 in June, 2009 (Table-4). In Laldiggi Pond, minimum density (21 No/m^2) in February, 2009 and maximum density (175 No/m^2) was noted in month of January, 2010 (Table-5), whereas in Chautal Pond, minimum density (28 No/m^2) in November, 2009 maximum density (219 No/m^2) was recorded during March, 2009 (Table-6).

Asplanchna priodonta: Body is illoricate, transparent, polymorphic and with thin cuticle, body shape sacciform, bell shaped or with humps or projections; Foot absent; Corona comprised of a broken single ring of cilia (Sharma, 1998 a) (Plate- I). In Medical Pond it showed minimum density (21 No/m^2) in October, 2009 and maximum density (171 No/m^2) during June, 2009 (Table- 4). In Laldiggi Pond, it varied from minimum (25 No/m^2) in August, 2009 to maximum (271 No/m^2) during the months of November, 2009 (Table- 5), whereas in Chautal Pond, it ranged from minimum (58 No/m^2) in February, 2010 to maximum (305 No/m^2) in November, 2009 (Table- 6).

***Filinia* sp.:** Body is thin, barrel shaped and with two long movable antero lateral setae and one long immovable posterior seta usually folded ventrally (Sharma, 1998 a) (Plate- II). It showed minimum density (39 No/m^2) in April, 2009 and maximum density (173 No/m^2) during February, 2010 in Medical Pond. In Laldiggi Pond, it showed minimum (21 No/m^2) in June, 2009 and maximum density (228 No/m^2) during August, 2009, whereas in Chautal Pond, it showed minimum density (35 No/m^2) in March, 2009 while maximum density (253 No/m^2) during June, 2009 (Tables-4, 5, 6).

***Notholca* sp.:** Its lorica is oval to elongate and spindle shaped, with six occipital spines. Dorsal plate is with longitudinal striations; Foot absent (Plate- II). It showed minimum density (28 No/m^2) in November, 2009 and maximum density (139 No/m^2) during January, 2010 in Medical Pond (Table- 4). In Laldiggi Pond, it also showed minimum (72 No/m^2) during February, 2009 and maximum density (311 No/m^2) during October, 2009 (Table-5), whereas in Chautal Pond, it showed minimum density (53 No/m^2) in December, 2009 and maximum (191 No/m^2) density during May, 2009 (Table-6).

***Hexarthra* sp.:** Body is conical with six arms like appendages and pinnate bristles at their tips. Corona wavy, with double band of cilia and with or without ventral lip (Sharma, 1998 a). It showed minimum density (52 No/m^2) during March, 2009 and maximum density (296 No/m^2) during January, 2010 in Medical Pond. In Laldiggi Pond, minimum density (21No/m^2) was recorded during March, 2009 and maximum density (228 No/m^2) was recorded during August, 2009. In Chautal Pond, it showed minimum density (38 No/m^2) during January, 2010 and maximum density (197 No/m^2) during March, 2009 (Tables- 4, 5, 6).

2.4 OSTRACODA

Introduction:

Superficially, the members of the subclass Ostracoda resemble miniature mussels and, therefore, "mussel shrimps" is an old European vernacular name (Edmondson, 1959). They have unsegmented body enclosed in two hinged valves and resemble tiny clams (Cole, 1983). They inhabit all types of substrates, both in standing and running waters, including rooted vegetation, algal mats, debris, mud, sand and rubble. Most of the fresh water ostracods are bottom dwellers, although some appear occasionally in plankton samples. Some of them burrow superficially in soft substrates. The great majority of individuals are found moving about on the substrate by means of beating movements of the first and second antennae, and to some extent by kicking of the caudal rami (Pennak, 1978). Such locomotion ranges from creeping and uncertain weak, tottering movements to rapid bouncing. Food consists mostly of bacteria, molds, algae and fine detritus but some of the larger species have been observed feeding on living and dead animals (Pennak, 1978). Ecologically, ostracods are omnivorous scavengers.

Result and Discussion:

Ostracoda formed fifth abundant group in Medical Pond; sixth in Laldiggi Pond and fourth in Chautal Pond. It was represented *Heterocypris*, *Stenocypris* and *Centrocypris*. Population density of Ostracods varied from a minimum of 142 No/m^2 in June, 2009 to a maximum of 392 No/m^2 in November, 2009 in Medical Pond, from 119 No/m^2 in October, 2009 to 486 No/m^2 in January, 2010 in Laldiggi Pond and from 272 No/m^2 October, 2009 to 722 No/m^2 in January, 2010 in Chautal Pond (Tables - 4, 5, 6). Its percent contribution varied from 4.78 % during June, 2009 to 11.58 % in November, 2009 in Medical Pond, from 4.11 % during October, 2009 to 9.75 % in June, 2009 in Laldiggi Pond and from 7.01 % during February, 2009 to 15.18 % in March, 2009 in Chautal Pond.

Statistically Ostracoda recorded negative correlation with water temperature (Medical Pond: r = -0.667; Laldiggi Pond: r = -0.595; Chautal Pond: r = -0.552) and with TDS in all the three selected ponds (Medical Pond: r = -0.572; Laldiggi Pond: r = -0.516; Chautal Pond: r = -0.493) (Table– 8), whereas it showed positive correlation with D.O. in all the three selected ponds (Medical Pond: r = 0.387; Laldiggi Pond: r = 0.900; Chautal Pond: r = 0.817) (Table– 8; Fig.- 16). Correlation between benthic species Diversity and Ostracods density showed positive correlation in Medical Pond (r = 0.282) and Laldiggi Pond (r = 0.495) and negative in Chautal Pond (r = - 0.174) (Table– 8).

According to Wetzel (1983), fluctuation in temperature is one of the important factors affecting parthenogenesis and their seasonal pattern of reproduction. A few species swim about actively above the substrate (Pennak, 1978). It can be said that monthly fluctuations in the density of ostracods may be due to the fluctuations in environmental conditions like depth, temperature, availability of food and nutrients and also variations in the predation pressure of the benthic animals (Pennak, 1978).

***Heterocypris* sp.:** Terminal segment of maxillary palp broadened distally (Edmondson, 1959) (Plate III). It was more common and offered maximum share of total Ostracods in all the selected waterbodies. It showed minimum (45 No/m^2) July, 2009 and maximum density (236 No/m^2) during February, 2009 in Medical Pond. In Laldiggi Pond, it showed minimum density (52 No/m^2) in October, 2009 and maximum density (372 No/m^2) in January, 2010, whereas in Chautal Pond, it showed minimum density (141 No/m^2) during June, 2009 and maximum density (593 No/m^2) during January, 2010 (Tables-4, 5, 6).

***Stenocypris* sp.:** Valves oblong, compressed, anterior margins with a conspicuous irregular canal system (Edmondson, 1959) (Plate III). It showed minimum (36 No/m^2) in June, 2009 and maximum density (98 No/m^2) during December, 2009 in Medical Pond. In Laldiggi Pond, it showed minimum density (23 No/m^2) in January, 2010 and maximum (91 No/m^2) density in June, 2010, whereas in Chautal Pond, it showed minimum density (56 No/m^2) during April, 2009 and maximum density (108 No/m^2) during June, 2009 (Tables-4, 5, 6).

Centrocypris sp. Shell boldly arched (Edmondson, 1959). It showed minimum density (23 No/m^2) in June, 2009 and maximum density (98 No/m^2) in December, 2009 in Medical Pond. In Laldiggi Pond, it was minimum (29 No/m^2) in October, 2009 and maximum (103 No/m^2) in May, 2009, whereas in Chautal Pond, it showed minimum density (31 No/m^2) during August, 2009 and maximum density (108 No/m^2) during May, 2009 (Tables-4, 5, 6).

2.5 OLIGOCHAETA

Introduction:

Except for a relatively small number of marine species, the oligochaetes are fresh water and terrestrial animals. The body is clearly divided into segments which are separated externally by distinct grooves. Anterior and dorsal to the mouth is the prostomium, a small extension which is variously modified in different species and has some diagnostic value. The mouth is contained in segment 1, the peristomium; posterior from this, the segments are numbered consecutively. The boundaries between the segments are indicated as 5/6, 6/7, etc. For the correct identification of many species or even genera, it is necessary to study the arrangement of internal organs, particularly the reproductive system. Many of the smaller worms, such as members of Aelosomatidae and Naididae, are widely distributed and may be found in nearly any part of the country; others are more restricted in their distribution (Edmondson, 1959).

Jakher (1980) reported five oligocheta belonging to three families i.e. Tubificidae *(Branchiura sowerbyi, Limnodrilus sp.)*, Naidae (*Branchiodrilus semperi, Pristina sp.*) and *Aelosomatidae (Aelosoma sp.)*. Many other Indian limnologist during their studies on macrobenthic fauna also reported poor oligochaetes species composition. Srivastava (1959a) found five oligochaetes species from the littoral zone of two lakes. Krishnamurthy (1966) reported only two oligochaetes (*Tubifex* and *Nais*) from Tungabhadra reservoir.

Result and Discussion:

Oligochaeta formed eighth abundant group in Medical Pond; seventh in Laldiggi Pond and sixth in Chautal Pond. This group was represented by *Tubifex*, *Chaetogaster, Nais and Aelosma.* Maximum oligochaetes 288 No/m^2 in the month of December, 2009 in Medical Pond, 286 No/m^2 in the month of January, 2010 in Laldiggi Pond and 333 No/m^2 in the month of July, 2009 in Chautal Pond, were recorded, whereas the minimum 156 No/m^2 during February, 2009, 197 No/m^2 during April, 217 No/m^2 during November, 2009 were recorded in Medical Pond, Laldiggi Pond and Chautal Pond respectively.

The total percent contribution of Oligochaeta to the overall density of benthic fauna ranged from 4.53 % during February, 2009 to 8.87 % in September, 2009 in Medical Pond, from 4.63 % during February, 2009 to 9.13 % in June, 2009, in Laldiggi and from 4.02 % during December, 2009 to 10.78 % during July, 2009 in Chautal Pond.

Statistically Oligochaeta recorded negative correlation with water temperature (Medical Pond: r = -0.187; Laldiggi Pond: r = -0.180; Chautal Pond: r = -0.527) (Table- 8), whereas it showed positive correlation with D.O. in all the three selected ponds (Medical Pond: r = 0.435; Laldiggi Pond: r = 0.678; Chautal Pond: r = 0.133) (Table- 8). It showed positive correlation with TDS in Laldiggi Pond (r = 0.318) and Chautal Pond (r = 0.309) and negative in Medical Pond (r = -0.457) and with diversity index it showed positive correlation in Medical Pond (r = 0.114), Laldiggi Pond (r = 0.403) and in Chautal Pond (r = 0.223) (Table- 8). Correlation between benthos species Diversity and Oligochaeta density showed insignificant positive correlation in all the three ponds in Medical Pond (r = 0.114), Laldiggi Pond (r = 0.403) and Chautal Pond (r = 0.223) (Table- 8).

Jakher (1980) also reported highest number of Oligochaetes during winter season, whereas Mehrotra (1988) observed maximum number during rainy season. The oligochaetes have been represented by *Tubifex, Chaetogaster, Nais* and *Aelosma* and dominance was recorded by *Tubifex* in all three selected waterbodies. Cowell and Vodopich (1981) have found uniformity in the abundance of oligochaetes throughout the year. The general distribution pattern of these worms showed that they preferred more eutrophic areas having low oxygen, and high organic matter. As these sludge worms feed mostly on bacteria down to 10 cm below the sediment surface (Brinkhurts, 1974), the availability of food, polluted environment and absence of predation might be the cause of higher numbers of oligochaetes population in these ponds.

Tubifex: Two latera teeth of dorsal pectinate setae; widely divergent length of atrium and penis combined much shorter than the remainder of sperm duct (Edmondson, 1959) (Plate IV). Its population density varied from a minimum of 39 No/m^2 in April, 2009 to a maximum of 98 No/m^2 in October, 2009 in Medical Pond, from 41 No/m^2 in April, 2009 to 92 No/m^2 in January, 2010 in Laldiggi Pond and from 34 No/m^2 in December, 2009 to 92 No/m^2 in August, 2009 in Chautal Pond (Tables- 4, 5, 6).

Chaetogaster: without dorsal setae, prostomium well developed, pointed with long sensory hairs (Edmondson, 1959) (Plate IV). Its population density varied from a minimum of 29 No/m^2 in July, 2009 to a maximum of 81 No/m^2 in December, 2009 in Medical Pond, from 36 No/m^2 in April, 2009 to 85 No/m^2 in October, 2009 in Laldiggi Pond and from 47 No/m^2 in November, 2009 to 95 No/m^2 in July, 2009 in Chautal Pond (Tables- 4, 5, 6).

Nais: Eyes normally present, ventral setae of segments 2 to 5 mostly well differentiated from those of more posterior segments (Edmondson, 1959) (Plate IV). Its population density varied from a minimum of 30 No/m^2 in July, 2009 to a maximum of 79 No/m^2 in December, 2009 in Medical Pond, from 27 No/m^2 in February, 2009 to 95 No/m^2 in July, 2009 in Laldiggi Pond and from 39 No/m^2 in February, 2009 to 93 No/m^2 in July, 2009 in Chautal Pond (Tables- 4, 5, 6).

Aelosoma: Septa imperfectly developed; ventral setae bundles containing hair setae; prostomium usually broad and ventral ciliated; mostly with oil globules in the integument (Edmondson, 1959) (Plate IV). Its population density varied from a minimum of 37 No/m^2 in September, 2009 to a maximum of 73 No/m^2 in May, 2009 in Medical Pond, from 46 No/m^2 in June, 2009 to 65 No/m^2 in September, 2009 in Laldiggi Pond and from 53 No/m^2 in October, 2009 to 73 No/m^2 in January, 2010 in Chautal Pond (Tables- 4, 5, 6).

2.6 EGGS AND NAUPLII

During present study, different developmental stages of benthos were recorded together as Eggs and Nauplii. Larval morphology is not known in most species of copepods. Sub-adult copepods, especially in cyclopoids, are usually mistaken for adults by the beginners. Hence, it is necessary to differentiate an immature individual from its adults (Reddy, 2001). Copepod hatch into a small compact active free swimming larva called Nauplii which have three pairs of appendages (Pennak, 1978) (Plate- IV). There are altogether six successive nauplier stages, which feed, grow, moult and acquire further appendages (Wetzel, 1983). After six nauplier moults, an enlarged and more elongated form of the first copepod instar develops. There are five copepodite stages during which additional appendages and body segments develop. The sixth and final copepodite stage is adult (Reddy, 2001). The time required to complete juvenile stage is highly variable depending upon various environmental conditions (Wetzel, 1983).

In the present investigation, nauplier stages were observed throughout the period of investigations. Indicating that reproduction in copepods is carried out throughout the year. Pennak (1978) has also reported that reproduction in some species of copepods is carried out throughout the year having three or more generations. Hillbricht *et al.* (1988) have reported increased fecundity at high temperature. Miracle and Serra (1989), however, have reported negligible effect of temperature on the fecundity of rotifers.

2.7 DIPTERA

Introduction:

Diptera have aquatic larvae and pupae with terrestrial adults. Many other aquatic insects are also commonly referred to as "flies" (e.g., mayflies, dragonflies, stoneflies, caddisflies, alderflies, fishflies), but these taxa are not true flies as they do not belong to the order Diptera. When referring to true flies or Diptera with their common names, the word "fly" is separate (e.g., crane fly, black fly, moth fly dance fly, flower fly). The true flies are extremely important in aquatic food webs and often are the most diverse and abundant macroinvertebrate taxon collected in many freshwater habitats. Diptera inhabit a wide range of habitats and some taxa are extremely tolerant and occur in heavily polluted water bodies. Some true flies can be a nuisance due to their blood feeding behaviors. Most Diptera larvae are maggot-like or worm-like. Some possess an obvious head capsule, but this structure is either reduced or obscured in many other dipteran taxa. In all dipteran larvae, segmented legs and wing pads are absent from the thorax. Because of the large diversity of aquatic Diptera and the lack of easily observable and consistent characters in their larvae, the identification of larvae can be difficult. Common diagnostic characters for aquatic Dipteran larvae include the number and location of prolegs, shape of the terminal processes, and head condition (e.g., well-defined or reduced head capsule). Egg-laying in this family is curious. The female finds a twig over-hanging a stream and lays an egg mass. She then stays with the eggs until she dies. Other females are attracted to the same spot and a clump of dead flies and egg masses eventually accumulates. When the larvae hatch they must crawl through the mass of fly carcasses in order to drop into the stream below. Some ceratopogonid larvae inhabit semiaquatic areas such as moist sand or mud. Common species are snake-like and are similar to chironomids except that most ceratopogonids lack prolegs. Chironomids are the most abundant and diverse group of aquatic insects. They are found in almost any water body and comprise more than 50% of the species richness. Some kinds of chironomids are blood red (this color is lost when the specimen is preserved). The red coloration comes from hemoglobin that allows the larvae to store oxygen and survive in situations with low dissolved oxygen. Chironomids are an important food source for insects, fishes, and birds.

Result and Discussion:

Diptera formed the second abundant group of benthic fauna in Medical Pond and Laldiggi Pond and third in Chautal Pond. It was represented by *Chironomus, Helius, Culex* and *Pentaneura*. The monthly variations in population density of Diptera (No/m^2) in the selected water bodies are given in Tables-4, 5, 6. The density of Diptera ranged from a minimum of 218 No/m^2 during August, 2009 to a maximum of 879 No/m^2 in December, 2009 in Medical Pond, from 188 No/m^2 during June, 2009 to 1262 No/m^2 in January, 2010 in Laldiggi Pond and from 248 No/m^2 during April, 2009 to 1401 No/m^2 in January, 2010 in Chautal Pond.

The percent contribution of Diptera to the total benthos ranged from 8.39 % during August, 2009 to 23.31 % in May, 2009 in Medical Pond, from 6.52 % during June, 2009 to 25.28 % in October, 2009 in Laldiggi Pond and from 7.14 % during April, 2009 to 22.25 % in January, 2010 in Chautal Pond.

Statistically Diptera recorded a significant negative correlation with water temperature (Medical Pond: r = -0.654; Laldiggi Pond: r = -0.716; Chautal Pond: r = -0.655)) (Table– 8; Fig.-8), TDS (Medical Pond: r = -0.538; Laldiggi Pond: r = -0.705; Chautal Pond: r = -0.535) and nitrate (Medical Pond: r = -0.570; Laldiggi Pond: r = -0.676; Chautal Pond; r= -0.643, whereas significant positive correlation with D.O. in all the three selected Ponds (Medical Pond: r = 0.647; Laldiggi Pond: r = 0.593; Chautal Pond: r = 0.876) (Table-8; Fig.-17). It showed negative correlation with diversity index in Medical Pond (r = -0.534) and Chautal Pond (r = -0.378) and positive in Laldiggi Pond (r = 0.261). Correlation between benthic species Diversity and Diptera density showed significant negative correlation in Medical Pond (r = - 0.534), whereas insignificant positive in Laldiggi Pond (r = 0.261) and insignificant negative in Chautal Pond (r = - 0.378) (Table -8).

Chironomus larva: Middle tooth of labial plate trified or notched at base: eleventh body segments with two pairs of ventral blood gills (Pennak, 1978) (Plate - V). *Chironomus* larva was very common and found to be the most abundant species throughout the period of study in all the three selected ponds. Its density varied from a minimum of 67 No/m^2 in August, 2009 to a maximum of 595 No/m^2 in January, 2010 in Medical Pond, from 98 No/m^2 in June, 2009 to 675 No/m^2 in January, 2010 in Laldiggi Pond and from 105 No/m^2 in October, 2009 to 1014 No/m^2 in January, 2010 in Chautal Pond (Tables- 4, 5, 6).

Chironomus pupa: Thoracic respiratory organ a tuft of numerous filaments (Pennak, 1978) (Plate - V). Its population density varied from a minimum of 9 No/m^2 in October, 2009 to a maximum of 59 No/m^2 in March, 2009 in Medical Pond, from 3 No/m^2 in May, 2009 to 79 No/m^2 in January, 2010 in Laldiggi

Pond and from 2 No/m^2 in March, 2009 to 78 No/m^2 in January, 2010 in Chautal Pond. It was found to be present during the most of the study period in all the selected water bodies (Tables- 4, 5, 6).

Helius larva: Creeping welts on ventral side of abdominal segments or absent (Pennak, 1978) (Plate - V) (Tables- 4, 5, 6).

Its density varied from a minimum of 5 No/m^2 in July, 2009 to 29 No/m^2 in January, 2010 in Medical Pond, from 3 No/m^2 in November, 2009 to 28 No/m^2 in March, 2009 in Laldiggi Pond and from 3 No/m^2 in April and August, 2009 to a maximum of 27 No/m^2 in January, 2010 in Chautal Pond (Tables- 4, 5, 6).

Culex: have several pairs of hair tufts on the breathing tube; the tube is relatively long and slender (Pennak, 1978) (Plate - V); Postcircular bristles absent in adults.

Its population density varied from a minimum of 14 No/m^2 in June, 2009 to a maximum of 216 No/m^2 in September, 2009 in Medical Pond, from 33 No/m^2 in April, 2009 to 145 No/m^2 in September, 2009 in Laldiggi Pond and from 28 No/m^2 in April, 2009 to 147 No/m^2 in November, 2009 in Chautal Pond (Tables- 4, 5, 6).

Pentaneura larva: Segments of the body with a scattered bristles; body slender; both pairs of anal gills close to anal openings (Pennak, 1978) (Plate - V).

Its population density varied from a minimum of 54 No/m^2 in January, 2010 to a maximum of 298 No/m^2 in October, 2009 in Medical Pond, from18 No/m^2 in June, 2009 to 424 No/m^2 in January, 2010 in Laldiggi Pond and from 29 No/m^2 in March, 2009 to 195 No/m^2 in June, 2009 in Chautal Pond (Tables- 4, 5, 6).

2.8 HEMIPTERA

Introduction:

Aquatic hemipteran adults and larvae unlike most aquatic taxa in that the adults and larvae occupy the same habitat. Aquatic and semiaquatic Hemiptera can be separated into two groups based on their antennal morphology and the habitat in which they are generally found. Some Hemiptera are primarily aquatic and can be recognized by the possession of antennae that are shorter than the head and concealed below the eye. One exception is the gelastocoridae, which are riparian and possess short antennae. The truly aquatic species are usually found under water, but many possess wings, which allow movement between water bodies. In contrast, most semiaquatic species of Hemiptera have antennae longer than their heads and can be found on the water's surface or at the water's margin. Although some taxa are primarily aquatic, most Hemiptera do not rely heavily on dissolved oxygen in the water, but instead obtain oxygen from the atmosphere. Due to their ability to utilize atmospheric oxygen, Hemiptera are often able to exist in water bodies with low levels of dissolved oxygen. Most aquatic and semi-aquatic Hemiptera are predatory. After grasping a prey item, these predatory hemipterans inject enzymes into the prey with their beak or rostrum, first to poison and then to digest the insides of their prey. The softened internal structures of the prey are then sucked up through the beak. Some species of these Hemiptera can inflict a painful bite in self-defense when handled (e.g., *Belostomatidae, Naucoridae, Nepidae*). The following key includes known families as well as number of families that likely occur in Mongolia, but this remains to be confirmed. The most distinctive characteristic of both immature and adult Hemiptera is the presence of mouthparts that are modified into an elongate, sucking beak. Most hemipteran adults possess "hemelytra", which are modified fore-wings with a leathery base and membranous distal half. Some adults and all larvae lack wings, but most mature larvae possess wing pads. Both adults and larvae have three pairs of segmented legs and there are two tarsal claws present on at least some of the legs. The shape and length of the antennae, legs, and beak (i.e., rostrum) can be important for separating Hemiptera families. Body shape and the presence or absence of veins in the wing membrane is also diagnostic for some taxa. These insects feed on dead and dying insects that fall onto the water surface or onto the mats they inhabit.

Heteroptera insects like all higher organisms, require a source of oxygen. Since water does not contain as high a volume of oxygen as air, so alternate breathing methods were developed. Aquatic breathing methods may be divided into two types, aeropneustic and hydropneustic (Usinger, 1968; McCafferty, 1981). Aeropneustic breathing methods allow the insect to continue to utilize surface air for respiration. A good example of this type of respiration is found in the water scorpions belonging to family nepidae (Usinger, 1968; McCafferty, 1981). Periodic contact breathers move to the surface to replenish an air supply which they carry with them, they may dive and swim around (Usinger, 1968; McCafferty, 1981). Often this is done in a chamber under the wing.

Result and Discussion:

Hemiptera formed sixth abundant group in Medical Pond; fifth in Laldiggi Pond and Seventh in Chautal Pond. Hemiptera are represented by species viz *Notonecta, Coroxid, Belostoma, Hebrus, Sigara* and *Hespercorixa*. The monthly variations in density of various taxa of Hemiptera (No/m^2) in the selected water bodies are given in Tables-4, 5, 6. The population density of Hemiptera ranged from a minimum of 141 No/m^2 during July, 2009 to a maximum of 552 No/m^2 in December, 2009 in Medical Pond, from 143 No/m^2 during October, 2009 to 579 No/m^2 in December, 2009 in Laldiggi Pond and from 81 No/m^2 during March, 2009 to 564 No/m^2 in December, 2009 in Chautal Pond. Total percent contribution of Hemiptera ranged from 4.28 % during October, 2009 to 12.88 % during December, 2009 in Medical Pond, from 4.93 % during October, 2009 to 12.57 % in December, 2009 in Laldiggi Pond and from 2.65 % during March, 2009 to 10.12 % in December, 2009 in Chautal Pond.

Statistically Hemiptera recorded a significant negative correlation with water temperature (Medical Pond: r = -0.712; Laldiggi Pond: r = -0.676; Chautal Pond: r = -0.596), whereas it showed significant positive correlation with D.O. in all the three selected Ponds (Medical Pond: r = 0.772; Laldiggi Pond: r = 0.889; Chautal Pond: r = 0.860) (Table– 8; Fig. 18). It showed negative correlation with TDS in all the three selected ponds (Medical Pond: r = -0.350; Laldiggi Pond: r = -0.552; Chautal Pond: r = -0.450) and with diversity index it showed insignificant negative correlation in Medical Pond (r = -0.188) and Chautal Pond (r = -0.088) but significant positive in Laldiggi Pond (r = 0.675). Correlation between benthic species Diversity and Hemiptera density showed insignificant correlation in all the water bodies except Laldiggi Pond where it was significant positive (Medical Pond: r = -0.188; Laldiggi Pond: r = 0.675; Chautal Pond: r = -0.088) (Table-8).

Notonecta insulata: *Notonecta* is commonly called as Backswimmers. This group is predatory. Notonectids most commonly occur along vegetated margins of lakes and ponds and in marshes. The size is small to medium (5-15 mm). Body cylindrical; antennae shorter than head, concealed below eye; beak cylindrical; hind legs oar-like; hind tarsal claws inconspicuous. The last antennal segment is much shorter than the penultimate (Needham and Needham, 1962) (Plate - VII). Although notonectids spend most of their time hanging from the water surface at an angle with the tip of their abdomens in contact with the surface film, they were recorded in benthic samples. These bugs store air on the ventral side of their abdomens and under their wings. The coloration of notonectids is reversed compared to many other aquatic organisms. They are generally dark ventrally and light dorsally because they swim on their backs. The antennae are four segmented; hemelytra are usually longer than the clavicle commissure (Triplehorn and Norman, 2005).

Its population density varied from a minimum of 11 No/m^2 in September, 2009 to a maximum of 263 No/m^2 in December, 2009 in Medical Pond, from 54 No/m^2 in April, 2009 to 218 No/m^2 in December, 2009 in Laldiggi Pond and from 11 No/m^2 in July, 2009 to 186 No/m^2 in January, 2010 in Chautal Pond (Tables- 4, 5, 6).

Belostoma sp.: These are commonly called as Giant Water Bugs. Belostomatids most commonly occur in lakes, ponds, and marshes and less commonly in pools and backwaters in streams and rivers. They are usually associated with aquatic vegetation. The size is Large (25-45 mm). Body flattened and oval; antennae shorter than head, concealed below eye; beak cylindrical; fore-legs raptorial; mid and hind legs fringed with swimming hairs; fore wing membrane with veins; a pair of strap-like appendages present at apex of abdomen. First or basal segment of beak longer than the second; furrow of the wing membrane nearly or quite straight; length about 1 inch or less (Needham and Needham, 1962) (Plate - VII). Belostomatids are superficially very similar to naucorids, especially as larvae. Belostomatids are voracious predators and have been observed attacking fish up to 9 cm long. They are sometimes called "toe biters" because when handled carelessly or stepped on, belostomatids can inflict a painful bite with their beak or rostrum.

It is found to be absent throughout the study period in Medical Pond. In Laldiggi Pond it was varied from 5 No/m^2 in May, 2009 to 58 No/m^2 in January, 2009 and in Chautal Pond from 2 No/m^2 in November, 2009 to 87 No/m^2 in January, 2010 (Tables- 4, 5, 6).

***Coroxid* sp.**: *Coroxid* commonly called as Water Boatmen. The Feeding habitat is Collector/Gatherers. Coroxids are found in areas of standing or slow flowing water in ponds, lakes, marshes, streams, and rivers. The size of this group is small (3-11 mm). Antennae shorter than head, concealed below eye; beak broad and triangular without distinct segments; fore tarsus scooplike and edged with setae. Coroxids feed differently than most other hemipterans. Most coroxids feed by disturbing soft sediments and detritus with their scoop-like fore-legs and consuming organisms stirred up from the sediment. These bugs breathe by using an air bubble held under their wings, which must be renewed periodically by breaking the surface of the water. (Plate - VII).

Its population density varied from a minimum of 32 No/m^2 in September, 2009 to a maximum of 198 No/m^2 in December, 2009 in Medical Pond, from 13 No/m^2 in October, 2009 to 126 No/m^2 in December, 2009 in Laldiggi Pond and 12 No/m^2 in March, 2009 to 173 No/m^2 in December, 2009 in Chautal Pond (Tables- 4, 5, 6).

***Hebrus* sp.**: *Hebrus* is commonly called as Velvet-Water Bugs. Feeding habitat of this Group is predators. Hebrids occur at the margins of ponds, marshes, and streams or on the surface of floating mats of vegetation in these habitats. Size is small (1-2.5 mm). Body short and stout and covered in fine hairs; antennae longer than head; beak cylindrical; membrane not veined (in winged forms); 2 tarsal segments (first segment short and second segment long); claws inserted at apex. These stocky insects are often overlooked because of their small size (Plate- VII). When disturbed, hebrids often crawl beneath the water surface.

It is found to be absent throughout the study period in Medical Pond. In Laldiggi Pond it varied from 5 No/m^2 in October, 2009 to 115 No/m^2 in January, 2009, whereas in Chautal Pond, from 3 No/m^2 in June, 2009 to a maximum of 39 No/m^2 in December (Tables- 4, 5, 6).

Sigara sp.: Hemelytral pattern not reticulate; hemelytra and face not hairy; 2.4 to 9.2 mm long (Pennak, 1978) (Plate - VII).

Its population density varied from a minimum of 2 No/m^2 in November, 2009 to a maximum of 23 No/m^2 in September, 2009 in Medical Pond. In Laldiggi Pond, its population density varied from 2 No/m^2 in January, 2010 to 51 No/m^2 in December, 2009, whereas in Chautal Pond from 2 No/m^2 in March, 2009 to 47 No/m^2 in June, 2009. It was also noted present throughout the study period in all the three selected water bodies (Tables- 4, 5, 6).

The abundance of Hemiptera in Medical Pond, Laldiggi and Chautal Pond, in present study can be related to presence of macro- vegetation/ macrophytes in these Ponds. Tonapi (1959) and Lansbury (1957) have observed abundance of these insects from July to September in Poona waters, whereas Das and Bhist (1979) found dominance of this group from March to June in Kumaun lakes, Uttar Pradesh.

Hesperocorixa sp.: The body is elongate-oval, somewhat flattened, and usually dark grey. The dorsal surface of the body is cross-line. The middle and the hind legs are elongate, and the hind legs are oar-like (Triplehorn and Norman, 2005). First tibia with a group of hairs near the outer margin; 6.3-11.4 mm long (Pennak, 1978) (Plate - VII).

Its population density varied from a minimum of 27 No/m^2 in July, 2009 to a maximum of 196 No/m^2 in January, 2010 in Medical Pond, from 21 No/m^2 in May, 2009 to 149 No/m^2 in December, 2009 in Laldiggi Pond and from 17 No/m^2 in March, 2009 to 148 No/m^2 in December, 2009 in Chautal Pond. Furthermore, it was recorded present throughout the period of study in all selected Ponds (Tables- 4, 5, 6).

2.9 COLEOPTERA

Introduction:

Aquatic Coleoptera constitute an important part of the macro-zoobenthos of freshwater habitats. Small and temporary water bodies have more species than large and permanent ones (Larson, 1985).

Beetles are the group of insects with the largest number of known species. They are classified in the order Coleoptera (from Greek , koleos, "sheath"; and , pteron, "wing", thus "sheathed wing"), which contains more described species than in any other order in the animal kingdom, constituting about 25% of all known life-forms. About 40% of all described insect species are beetles (about 400,000 species), and new species are frequently discovered. The order Coleoptera is a huge order, of which the majority of members are terrestrial. However, there are still a great number of beetles adapted to an aquatic existence encompassing a large diversity of habitats and life histories. Aquatic beetles can be found in nearly any aquatic habitat, but beetles reach their greatest diversity in lentic habitats such as wetlands and pond margins. Part of the reason for their success in aquatic habits is the ability of the adults to enter or leave the water to search for mates or to search for better conditions. Some beetles are aquatic as both larvae and adults, while others are aquatic as adults or as larvae. However, almost all aquatic and semiaquatic Coleoptera pupate terrestrially with the exception of a few taxa (e.g. Psephenidae, Scirtidae). Aquatic beetles have their greatest abundance and diversity in the temperate regions (Spangler, 1982). These insects are not particular in their choice of water bodies and occur in wide variety of habitats (Galewwski, 1971; Zaitsev, 1953), although many species may prefer certain types of water bodies (Hosseinie, 1978). Many of them especially dytiscids and many hyropphilids are generally found in habitats as small, shallow water bodies or margins of rivers and marshes and they occupy the zone of emergent vegetation, mats of plant debris or flooded terrestrial vegetation along the shore line (Jach and Margalit, 1987). On the other hand some aquatic beetles such as Noterids are common among roots of floating plants (Saleh *et al.*, 1991; Zalat *et al.*, 2000).

Larvae of aquatic Coleoptera can be recognized by the presence of a sclerotized head, three pairs of segmented thoracic legs, and the absence of wing pads.

Characters such as the number of tarsal claws, number of leg segments, body shape, and antennal length are diagnostic characters for Coleoptera larvae. Coleoptera adults can be recognized primarily by the presence of heavily sclerotized fore wings (elytra) which lack veins and cover the membranous hind wings. In addition, the entire body is generally hardened and three pairs of segmented legs are present. Adult Coleoptera families can be separated by characters such as the shape of the eye, the hind coxae, and the antennae.

Result and Discussion:

Coleoptera formed fourth abundant group in Medical Pond; eighth in Laldiggi Pond and seventh in Chautal Pond. This group was represented by *Hydrophilus, Dytiscus, Berosus* and *Haliplus*. The monthly variations in population density of various genera of Coleoptera (No/m^2) are given in Tables-4, 5, 6. The population density of Coleoptera ranged from a minimum of 86 No/m^2 during July, 2009 to a maximum of 438 No/m ^{2} in October, 2009 in Medical Pond, from 94 No/m^2 during May, 2009 to 461 No/m^2 in January, 2010 in Laldiggi Pond and from 128 No/m^2 during March, 2009 to 403 No/m^2 in January, 2010 in Chautal Pond.

The total percent contribution of Coleoptera to the overall density of benthic fauna ranged from 4.00 % during July, 2009 to 12.52 % in October, 2009 in Medical Pond, from 3.10 % during May, 2009 to 9.23 % in June, 2009, in Laldiggi and from 4.06 % during June, 2009 to 10.12 % during December, 2010 in Chautal Pond.

Statistically Coleoptera recorded a significant negative correlation with water temperature (Medical Pond: r = -0.721; Laldiggi Pond: r = -0.741; Chautal Pond: r = -0.669), whereas significant positive correlation with D.O. (Medical Pond: r = 0.667; Laldiggi Pond: r = 0.825; Chautal Pond: r = 0.693) in all the three selected Ponds (Table- 8; Fig.- 10, 19). It showed negative correlation with TDS in all the three selected Ponds (Medical Pond: r = -0.463; Laldiggi Pond: r = -0.481; Chautal Pond: r = -0.328) and with diversity index, it showed positive correlation in Medical Pond (r = 0.184) and Laldiggi Pond (r = 0.591) and negative in Chautal Pond (r = -0.201). Correlation between benthos species Diversity and Coleoptera density showed insignificant positive correlation in two ponds except Chautal Pond (Medical Pond: r = 0.184; Laldiggi Pond: r = 0.591, and Chautal Pond: r = -0.201) (Table- 8).

Hydrophilus larva: *Hydrophilus* are commonly called as minute Moss Beetles. These are Collector/Gatherers (larvae possibly predators). Hydraenids are semiaquatic and occur just above the waterline along streams and other waterbodies. The size of larvae (1-3 mm) and adults (1-2 mm) is small. Legs well developed; abdominal segments 1-8 with a wide sclerite; urogomphi present on abdominal segment 9 and consisting of two segments; 10th abdominal segment with hooks. Adults are similar to hydrophilids; very small; antennal club with 5 segments with last segment before the club cuplike; Hydraenids are not commonly collected because of their small size and because they are semiaquatic. Each mandible with a single inner tooth (Pennak, 1978) (Plate - VI).

Its density varied from a minimum of 15 No/m^2 in July, 2009 to a maximum of 124 No/m^2 in February, 2010 in Medical Pond. In Laldiggi Pond, it ranged from 13 No/m^2 in March, 2009 to 118 No/m^2 in January, 2010, whereas in Chautal Pond, 14 No/m^2 in March, 2009 to 98 No/m^2 in May, 2009 (Tables- 4, 5, 6).

***Dytiscus sp.**:* Hind tibiae distinctly longer than broad (Pennak, 1978), hind legs are flattened and fringed with long hairs (Triplehorn and Norman, 2005) (Plate - VI).

Its population density varied from a minimum of 23 No/m^2 in June, 2009 to a maximum of 193 No/m^2 in October, 2009 in Medical Pond, in Laldiggi Pond from 24 No/m^2 in May, 2009 to 96 No/m^2 in January, 2010 and in Chautal Pond from 9 No/m^2 in March, 2009 to 89 No/m^2 in January, 2010 (Tables- 4, 5, 6).

Berosus larva: *Berosus* are commonly called as Water Scavenger Beetles. Larvae: Predators. Adults: Collector/Gatherers. The larvae and adults of water scavenger beetles most commonly occur in the standing and slow-moving waters of lakes, ponds, marshes, streams, and rivers; however, they occur in nearly any water body. They are usually found amongst aquatic vegetation. The larvae range in size from 2 to 60 mm and adults are small to large (1-40 mm). In Larvae: Mandibles large; legs with 4 segments; legs terminating in a single claw; end of abdomen generally blunt. Adults: Antennae clubbed with a cup-like segment at the base of 3-segmented club; hind coxae not extending posteriorly and dividing abdominal segment 1 into two sections. Hydrophilid beetles are the second most common and diverse family of beetles behind the dytiscids. Hydrophilid larvae and adults are good swimmers although not as good as dytiscids. Like dytiscid beetles, both larvae and adult hydrophilid beetles breathe atmospheric oxygen. The adults break the water surface head first in order to refill air stores under the wings. This is in contrast to dytiscid beetles, which break the water surface with their abdomen to refill their air supply. Larva with seven pairs of long, rigid, lateral, abdominal tracheal gills; legs and posterior abdominal segments are heavily fringed with hairs (Pennak, 1978) (Plate - VI).

Its population density varied from a minimum of 21 No/m^2 in July, 2009 to a maximum of 194 No/m^2 in March, 2009 in Medical Pond, from 18 No/m^2 in May, 2009 to 95 No/m^2 in February, 2010 in Laldiggi Pond and from 23 No/m^2 in March, 2009 to 125 No/m^2 in December, 2009 in Chautal Pond (Tables- 4, 5, 6).

***Haliplus* sp.**: *Haliplus* are commonly called as crawling water beetles. The feeding habitat is shredders. Haliplid beetle larvae and adults most commonly occur in standing and slow-moving waters in lakes, ponds, marshes, and streams. They are usually found associated with dense vegetation. Larvae size are large (5-12 mm) and adults are small (2-6 mm). Legs with 5 segments; one claw at end of each leg; abdomen terminating in 1-2 long filaments. Adults: antennae long and slender; elytra with indentations; legs lined with swimming hairs; hind coxae expanded into plates that cover abdominal segments 1-2 or 1-3 and bases of metafemora. Like most aquatic beetles the adults store air under their wings, but haliplid beetles are unique in having enlarged coxal plates that are also used to retain air. The air stored under the coxal plates is probably used less as an oxygen source than a means of maintaining buoyancy, allowing the adult to float to the surface rather than swim. The larvae spend most of their life underwater obtaining oxygen from the water. Haliplid adults and larvae are not very good swimmers and spend most of their time crawling among vegetation. The larvae move very slowly and will play dead when disturbed. Some kinds of the larvae are very distinctive with several long projections half as long as the body extending from most segments. Median portion of prosternum and prosternal process forming a plateau like elevation (Pennak, 1978); small to large (Plate - VI).

Its population density varied from a minimum of 23 No/m^2 in March and July, 2009 to a maximum of 118 No/m^2 in October, 2009 in Medical Pond, from 23 No/m^2 in May, 2009 to 166 No/m^2 in January, 2010 in Laldiggi Pond and from 24 No/m^2 in July, 2009 to 173 No/m^2 in February, 2010 in Chautal Pond (Tables- 4, 5, 6).

2.10 TRICHOPTERA

Introduction:

The name Trichoptera derived from the Greek words "trichos" meaning hair and "ptera" meaning wings refer to long, silky hairs that cover most of the body and wings. They are commonly known as "caddisflies" which mean case bearer. Trichoptera possess the more primitive characteristic state, having hairs rather than scales, and this character accounts for the name Trichoptera, and meaning "hairy wings.

Trichoptera, or caddisflies, comprise the most diverse insect order whose members are exclusively aquatic. Only aquatic Diptera outnumber them in species and ecological diversity. The larval stages are found in lakes, rivers, and streams around the world, and are important components of food webs in these freshwater ecosystems (Resh and Rosenberg, 1984).

Trichoptera is the largest order of insects in which most members are truly aquatic. Trichoptera are close relatives of butterflies and moths (Lepidoptera) and like Lepidoptera, caddisflies have the ability to spin silk. This adaptation may be largely responsible for the success of this group. Silk is used to build retreats, to build nets for collecting food, for construction of cases, for anchoring to the substrate, and to spin a cocoon for the pupa. Almost all caddisflies live in a case or retreat with the exception of rhyacophilidae. Caddisflies are important in aquatic ecosystems because they process organic material and are an important food source for fish. This group displays a variety of feeding habits such as filter/collectors, collector/gatherers, scrapers, shredders, piercer/herbivores, and predators. Like Ephemeroptera and Plecoptera, many Trichoptera species are sensitive to pollution. Larval Trichoptera resemble caterpillars except Trichoptera lack abdominal prolegs with crochets. Trichoptera can be identified by their short antennae, sclerotized head, sclerotized plate on thoracic segment one (and sometimes also on segments 2 or 3), soft abdomen, three pairs of segmented legs, and an abdomen that terminates in a pair of prolegs bearing hooks. Characteristics used to separate trichopteran families include sclerotization of the thoracic segments, presence or absence of abdominal humps, position and length of antennae, and the shape of the prolegs and associated anal claw. In many taxa, the shape and construction materials of a retreat or case can also be diagnostic. However in macroinvertebrate samples, the case is sometimes lost and morphological characters must be relied upon.

Result and Discussion:

Trichoptera formed ninth and second least abundant group in all the three water bodies. This group was represented by *Limnephilus, Phryganaea* and *Polycentropus.* The monthly variations in the population density of various genera of Trichoptera (No/m^2) are given in Tables- 4, 5, 6. The population density of Trichoptera ranged from a minimum of 4 No/m^2 during April, 2009 to a maximum of 15 No/m^2 in December, 2009 in Medical Pond, from 4 No/m^2 during April, 2009 to 15 No/m^2 in January, 2010 in Laldiggi Pond and from 4 No/m^2 during September, 2009 to 11 No/m ^{2} in January, 2010 in Chautal Pond.

Total percent contribution of Trichoptera is negligible and ranged from 0.138 % during April, 2009 to 0.350 % during December, 2009 in Medical Pond, from 0.106 % during April, 2009 to 0.347 % in June, 2009 in Laldiggi Pond and from 0.132 % during September, 2009 to 5.76 % in December, 2009 in Chautal Pond.

Statistically Trichoptera recorded a positive and significant correlation with dissolved oxygen (Medical Pond: r = 0.846; Laldiggi Pond: r = 0.642; Chautal Pond: r = 0.560) whereas, it showed negative correlation with water temperature in all the three selected ponds (Medical Pond: r = -0.757; Laldiggi Pond: r = -0.555; Chautal Pond: r = -0.499) (Table– 8; Fig.-11, 20). It showed negative correlation with TDS in all the three selected ponds (Medical Pond: r = -0.493; Laldiggi Pond: r = -0.380; Chautal Pond: r = -0.596) and with diversity index it showed negative correlation in Medical Pond (r = -0.268) and Chautal Pond (r = -0.481) and positive in Laldiggi Pond (r = 0.354). Correlation between benthic species Diversity and Trichoptera density showed insignificant negative correlation in Medical Pond (r = -0.268) and Chautal Pond (r = -0.481), whereas positive in Laldiggi Pond (r = 354) (Table- 8).

Limnephilus larva: *Limnephilus* are commonly called as Northern Case-Maker Caddisflies. These are belonging to shredders feeding Group. Limnephilus larvae occur in a wide range of habitats including small springs, large rivers, lakes, and marshes. They can be found just about anywhere in these habitats such as in snags, on rocks, and in vegetation. Size ranges from medium to large (8-35 mm). Antennae located midway between eye and mandible; prosternal horn present; pronotum and mesonotum heavily sclerotized; metanotum mostly membranous usually with small sclerites; anterior margin of mesonotum not notched at midline; dorsal and lateral humps present on abdominal segment 1; abdominal gills variable; a sclerotized plate present top of abdominal segment nine; chloride epithelia often present dorsally, laterally, and ventrally. *Limnephilus* caddisflies use a variety of materials including sand grains, sticks, and plant fragments to build their cases. The habitat influences the species present and the materials used in case construction. For example, species inhabiting cool flowing waters generally construct cases from mineral materials, whereas species in slow-moving warm waters often construct cases from vegetative material. This group contributed least.

Dorsal surface of the head without a stripe, or with diffused median coloration, pronotum without a distinct dark transverse band; case highly variable, composed of leaves, grass, twigs, sand, gravel, bark or wood arranged longitudinally or transversely (Pennak, 1978) (Plate - VIII).

Its population density varied from a minimum of 1 No/m^2 in September, 2009 to a maximum of 7 No/m^2 in January, 2010 in Medical Pond, from 1 No/m^2 in April and July, 2009 to 6 No/m^2 in December, 2009 in Laldiggi Pond and from 1 No/m^2 in April, July, September and October, 2009 to 5 No/m^2 in December, 2009 in Chautal Pond (Tables- 4, 5, 6).

***Phryganaea* larva**: *Phryganaea* are commonly called as Giant Case-Maker Caddisflies. These are belonging to feeding group: predators, herbivores. Phryganeid caddisfly larvae are commonly collected at the edges of ponds and lakes, in marshes, and in areas of slow current in streams. They are usually found in submerged aquatic vegetation, in overhanging grasses, and in accumulations of coarse detritus. The size ranges from 20 to 45 mm. Head and pronotum marked with conspicuous stripes; prosternal horn present; only pronotum well sclerotized; dorsal and lateral humps present on abdominal segment 1; a sclerotized plate is present on top of abdominal segment nine. These caddisflies can be very large when the larvae are full grown. Giant case-maker caddisflies feed on aquatic vegetation, filamentous algae, and invertebrates. Some species feed on vegetation when they are younger and then switch to invertebrates as they develop. These caddisflies build elongate cases constructed of plant fragments. Unlike other caddisflies, giant case-maker caddisflies can easily abandon their cases when they are disturbed. With small, pigmented sterna sclerite between the first coxae (Pennak, 1978); Case straight, bulky, and each end of case is open (Needham and Needham, 1962) (Plate - VIII).

Its population density varied from a minimum of 1 No/m^2 in March and April, 2009 to a maximum of 7 No/m^2 in December, 2009 in Medical Pond, from 1 No/m^2 in July, 2009 to 4 No/m^2 in September, December, 2009 and January, 2010 in Laldiggi Pond and from 2 No/m^2 in June, September and December, 2009 to 4 No/m^2 in March, 2009 in Chautal Pond (Tables- 4, 5, 6).

***Polycentropus* larva**: *Polycentropus* commonly called as Tube-Making and Trumpet-Net Caddisflies. These are belonging to feeding group:

collector/filterers, predators. Polycentropid caddisflies live in slow-flowing streams and rivers and in lakes and ponds. These caddisflies are generally found in warmer waters than many other trichopteran families. They build silken retreats on rocks and logs. Size ranges from medium to large (8 to 25 mm). Labrum rounded and sclerotized; only pronotum sclerotized; mesonotum and metanotum entirely membranous; trochantin pointed at apex; no sclerotized plate on top of abdominal segment nine; abdominal gills absent. Polycentropid caddisflies generally feed on invertebrates either by filtering them from the water or by ambushing invertebrates when they come close to the retreat. In some species, silk threads extended from the retreat are used to sense approaching prey. As with spiders, when a prey item touches a silk thread the polycentropid caddisfly senses the vibrations and attacks its victim. Larval tubes are trumpet shaped, opened at each end; the anterior end flared outward (Needham and Needham, 1962) (Plate - VIII).

Its population density varied from a minimum of 1 No/m^2 in April, May, September and November, 2009 to a maximum of 6 No/m^2 in December, 2009 in Medical Pond, from 1 No/m^2 in March, April and May, 2009 to 6 No/m^2 in January, 2010 in Laldiggi Pond and from 1 No/m^2 in April, September and October, 2009 to 4 No/m^2 in July, 2009 in Chautal Pond (Tables- 4, 5, 6).

Their low abundance and less diversity across these waterbodies clearly indicate that these insects are sensitive to pollution. It can be further concluded that these insects can live in polluted water which can be related to the availability of food and oxygen in these ponds in addition to other factors.

2.11 EPHEMEROPTERA (MAYFLIES)

Introduction:

Ephemeroptera comes from the Greek word, "ephemeros" meaning lasting a day and "pteron" means a wing. They are exoperygotes and hemimetabolus. Mayflies are all aquatic as naiads (Daly, 1998). Mayflies are common insects found in almost all freshwater habitats, as well as some brackish ones. There are about 2000 species (Hubbard and Peters, 1976; McCafferty and Edmunds, 1988) grouped in 231 genera (Covaci *et al.*, 2009) and 19 families. They are distributed throughout the planet except Antarctica, arctic regions and some isolated islands. The adults are soft bodied insects with very short antennae, vestigial mouthparts, two long cerci and usually a long caudal filament at the end of the abdomen.

Mayfly larvae are found in a variety of locations including lakes, wetlands, streams, and rivers, but they are most common and diverse in lotic habitats. They are common and abundant in stream riffles and pools, at lake margins and in some cases lake bottoms. All mayfly larvae are aquatic with terrestrial adults. In most mayfly species the adult only lives for 1-2 days. Consequently, the majority of a mayfly's life is spent in the water as a larva. The adult lifespan is so short there is no need for the insect to feed and therefore the adult does not possess functional mouthparts. Mayflies are often an indicator of good water quality because most mayflies are relatively intolerant of pollution. Mayflies are also an important food source for fish. Most mayflies have three caudal filaments (tails) although in some taxa the terminal filament (middle tail) is greatly reduced and there appear to be only two caudal filaments (only one genus actually lacks the terminal filament). Mayflies have gills on the dorsal surface of the abdomen), but the number and shape of these gills vary widely between taxa. All mayflies possess only one tarsal claw at the end of each leg. Characters such as gill shape, gill position, and tarsal claw shape are used to separate different mayfly families.

Result and Discussion:

Ephemeroptera formed tenth and least abundant group in all the selected water bodies. This group was represented by *Baetis* and *Caenis*. The population density of Ephemeroptera ranged from a minimum of 2 No/m^2 during April, 2009 to a maximum of 12 No/m^2 in January, 2010 in Medical Pond, from 3 No/m^2 during March, 2009 to 7 No/m^2 in November, 2009 in Laldiggi Pond and from 2 No/m^2 during March, 2009 to 9 No/m^2 in November, 2009 in Chautal Pond. Total percent contribution of Ephemeroptera is also negligible. It ranged from 0.069 % during April, 2009 to 0.378 % during September, 2009 in Medical Pond, from 0.077 % during March, 2009 to 0.189% in November, 2009 in Laldiggi Pond and from 0.065 % during March, 2009 to 0.231 % in November, 2009 in Chautal Pond.

Statistically Ephemeroptera recorded a significant negative correlation with water temperature (Medical Pond: r = -0.670; Laldiggi Pond: r = -0.647; Chautal Pond: r = -0.565), whereas it showed significant positive correlation with D.O. in all the three selected ponds (Medical Pond: r = 0.586; Laldiggi Pond: r = 0.783; Chautal Pond: r = 0.761) (Table- 8; Fig.-21). Correlation between benthic species Diversity and Ephemeroptera density showed insignificant correlation in all ponds (Medical Pond: r = 0.165; Laldiggi Pond: r = 0.441; Chautal Pond: r = -0.019) (Table- 8).

It has been reported that mayfly larvae are observed in fresh and clean waters only and are intolerant to organic pollution (Gaufin and Tarzwell, 1952; Krishnamoorthi and Sarkar, 1979). However, in present study mayfly larvae were found to be present in all the waterbodies, which has been related as highly polluted. This indicates that these larvae are able to survive in polluted waters provided there is sufficient oxygen (>2.8 mg/l).

Baetis – *Baetis* are commonly called as small Minnow Mayflies. These belong to feeding group: collector/gatherers, scrapers. These mayfly larvae are found in a variety of habitats and are widespread. Some are found in streams of moderate current or in areas of slack water. Other species are primarily restricted to lakes and ponds. The size ranges from small to medium (3 to 12 mm). Antennae in most genera 2-3x longer than the width of the head; gills present on abdominal segments 1 or 2 through 7; gill shape variable; 2-3; caudal filaments present. These mayflies are often very small and sometimes very abundant when conditions permit. Most baetid mayflies are good swimmers, hence the name minnow mayfly. Some species can be very common in polluted streams (Plate - IX).

Its population density varied from a minimum of 1 No/m^2 in April, 2009 to a maximum of 9 No/m^2 in February, September and November, 2009 in Medical Pond, from 1 No/m^2 in March, September, 2009 and January, 2010 to 4 No/m^2 in November, 2009 in Laldiggi Pond and from 1 No/m^2 in March, 2009 to 5 No/m^2 in May, 2009 in Chautal Pond (Tables- 4, 5, 6).

Caenis- *Caenis* are commonly called as Small Square-Gill Mayflies. These belong to feeding group, collector/gatherers, and scrapers. Caenis mayfly larvae occur in streams in areas of slow current, at the edges of lakes, and in wetlands. The size ranges from 2 to 8 mm. Gills on abdominal segment 1 vestigial (small and finger-like); gills on abdominal segment 2 square operculate (plate-like) and covering succeeding gills; operculate gills touch or overlap at midline; fringed gills present on abdominal segments 3-6; setae on caudal filaments restricted to apex of each annulation.

The operculate gills do not take up dissolved oxygen, but instead are used to cover and protect the other gills, which absorb dissolved oxygen from the water. Since these mayflies occur in areas where the current is slow, sediment can rapidly settle on the gills and prevent dissolved oxygen uptake. In order to keep their gills free of sediment, caenis mayflies wave their operculate gills. Head without horn like tubercles; 2-7 mm long (Pennak, 1978) (Plate - IX); widely distributed in ponds and slow streams.

In Medical Pond its population density varied from a minimum of 1 No/m^2 in April, 2009 to 5 No/m^2 in January, 2010, in Laldiggi Pond, from 1 No/m^2 in April and August, 2009 to a maximum of 4 No/m^2 in January, 2010, in Chautal Pond and from 1 No/m^2 in March, 2009 to 5 No/m^2 in October, November, 2009 and January, 2010 (Tables- 4, 5, 6).

Chapter V

Statistical Analyses

STATISTICAL ANALYSES

DIVERSITY

Introduction:

Diversity is an important structural attribute of a natural or organized community, which is related to other structural and functional properties such as productivity, niche structure, competition, stability and integration of the community. The sustaining of the so-called biological diversity is a priority of nature conservation in terrestrial, marine and freshwater environments (Brooks *et al.*, 2006). Therefore, the assessment of biological diversity and its probably most important element – taxonomic diversity plays a very significant role as the basis for nature protection. Various indices expressing the biological diversity of chosen groups of organisms are used as common metrics in biological assessment of environmental quality (Brooks *et al.*, 2006).

Biodiversity is one of the most important corner stones of sustainable development and represents the biological wealth of a given nation. The world, today is facing its greatest ever biodiversity crisis. Flora and fauna are becoming extinct because of habitat loss, overexploitation and the threat of global climate changes. Humans have long depended on aquatic resources for food, medicine, and materials as well as for recreational and commercial purposes such as fishing and tourism. Aquatic organisms also rely upon the great diversity of aquatic habitats and resources for food materials, and breeding grounds. Thus, aquatic biodiversity has enormous ecological, economical and aesthetic value and is largely responsible for maintaining and supporting overall environmental health.

Valuable aquatic resources are becoming increasingly susceptible to both natural and artificial environmental changes. Factors including overexploitation of species, the introduction of exotic species, pollution from urban, industrial and agricultural areas, as well as habitat loss etc. contribute to the declining levels of biodiversity in both freshwater and marine environments. Thus, conservation strategies to protect and conserve aquatic life are necessary to maintain the balance of nature and support the availability of resources for future generations.

The assumption that habitat degradation results in significant and predictable decrease in taxonomic diversity is an important objective of various methods of biological assessment based on freshwater organisms, especially on benthic invertebrates (Lenat, 1988; Jüttner *et al.*, 1996; Carlisle, 2008). The decrease in taxonomic diversity due to habitat degradation could be assessed as reduced species richness as e.g. stressors do not allow less tolerant species to colonize or to persist in degraded sites (Townsend and Hildrew, 1994). Stress condition in a pond eliminates sensitive taxa and results in reduced diversity and numerical dominance of those able to persist (Jones, 2008). The methods to assess long- and short term changes in biodiversity proposed by Lamb *et al.* (2009) can be applied in some well-studied, regularly and intensively assessed environments.

Biological indicators have the advantage of monitoring water quality over a period of time, providing more exact measures of anthropogenic effects on aquatic ecosystems, where physical and chemical data provide momentary evidence (Camargo *et al.*, 2004).

The diversity indices used in biological assessment studies are calculated for highly important indicator groups like Chironomidae (Cranston, 1995) and EPT (larval Ephemeroptera, Plecoptera and Trichoptera) or for a selected part of macrobenthic taxa (Barbour *et al.*, 1996), identified on the level of genus or family (Fleituch *et al.*, 2002), and much more rarely for all macrobenthos (Johnson and Hering, 2009). The idea that the groups richest in species should be excluded from the biomonitoring protocols to make the procedure easier has also been formulated (Rabeni and Wang, 2001). Some changes in biological diversity of aquatic organisms are based on data in which neither Insecta nor Oligochaeta are identified (Leppakoski *et al.*, 1999). The large, sometimes predominant part of total taxonomic diversity of stream macrobenthos is included within the groups that are difficult to identify, like Chironomidae, Limoniidae, Tipuliidae, Tabanidae and Oligochaeta. The so-called "lowest practical taxonomic level" used for identification by certain stream ecologists

(Waite *et al.*, 2004; Adams *et al.*, 2005) as a pragmatic compromise between increasing information content and increasing time and costs along the level of taxonomic detail (Jones, 2008) is very insufficient for the needs of biodiversity studies.

In numerous papers analyzing the relationships between environmental parameters and the diversity of some benthic invertebrate groups, have been typically omitted or treated as a single taxon (Jones, 2008). Unfortunately, those groups, more difficult than others to identify on the species level, are at once extremely rich in species and very important in terms of trophic function, e.g., larval Diptera. Therefore, conclusions from such studies about the reaction of diversity of macrobenthos to changes in environmental parameters seem to be controversial, when the most diverse taxonomic groups are identified on the level of genus or tribe (Statzner *et al.*, 2008).

Differences in taxonomic diversity of stream fauna due to environmental patterns have been documented in numerous studies, e.g., as the effect of moderate pollution (Barbour *et al.*, 1996; Koperski, 2005, 2009), climatic differences (Heino, 2002), oxygen depletion (Jacobsen, 2008), water flow velocity (Strzelec and Królczyk, 2004), organic matter accumulation and substratum characteristics (Graça *et al.*, 2004), type of bottom substrate (Jähnig *et al.*, 2008) and type of land-use in catchment area (Utz *et al.*, 2009).

A potentially great influence of a certain pattern on the results of diversity assessment, commonly neglected by researchers as diverse "attractiveness" and "accessibility" of sampling sites are presented by Sanchez-Fernandez *et al.* (2008). The diversity of Odonata seems to be strongly correlated with the local climatic specifics (Eversham and Cooper, 1998). Differences between the diversities of higher taxa as a result of divergence have been presented by Benke *et al.* (1984) and Jähnig *et al.*, (2008). The richness of four insect orders studied by Rosemond *et al.* (1992) was affected in different ways by chemical parameters of stream waters. The species richness and the values of Shannon-Weaver index were affected by various ecological variables and to the largest extent by chemical parameters of water (Beketov, 2004).

Species diversity: Species diversity is one of the basic concepts of ecology that has been used to characterize biological communities and ecosystems. At first glance, the concept appears to be rather simple but ecologists and mathematicians have been searching for ways to express the various aspects of species diversity since 1922 (Gleason, 1922). Species diversity increases as the number of species per sample increases and as the abundance of the species within a sample becomes more even (Pielou, 1969; Kricher, 1972).

Species evenness: The term evenness originates from the biological science, more particularly from biological studies (Magurrun, 1991; Nijssen *et al.,* 1998). Magurrun (1991) described evenness roughly as how equally abundant species are. More precisely evenness is a measure for the relative apportionment of abundance among the species present. Species evenness as species is more evenly distributed in a sample such that maximum evenness is obtained when all the species are equally abundant (DE Jong, 1975). Species evenness (equitably) is also a parameter which indicates relative awareness of the various species in a sample (DE Jong, 1975).

Result and Discussion:

1. **Shannon- Wiener's index of diversity**

The Shannon Wiener index is based on both the number of species present and relative abundance of each species. Monthly benthos species diversity in all the three selected water bodies is given in Tables – 9, 10, 11.

The index values for benthos diversity varied from a minimum of 3.11 in June, 2009 to a maximum of 3.23 in February, 2009 in Medical Pond, from 2.983 in October, 2009 to 3.208 in January, 2010 in Laldiggi Pond and from 3.002 in February, 2009 to 3.295 in August, 2009 in Chautal Pond. Correlation between species diversity (Shannon- Wiener's index) and some Physico-chemical parameters were also determined. In case of benthos, species diversity showed in significant negative correlation with water temperature in Medical Pond ($r = -0.041$) and Laldiggi Pond ($r = -0.246$), whereas significant positive in Chautal Pond ($r = 0.544$) (Table – 8). From our results and literature, it can be deduced that any disturbance in the environment or any shift inside the biological food chain pattern can cause marked changes in the composition of benthos and in the values of Shannon-Wiener diversity index as observed in the present study. In an exhaustive study by Ribera (2007) the diversity of lotic invertebrates is suggested to be determined by historical, geological and climatic constraints of habitats. Some researchers, however, explain the lack of significant effects of well-known environmental variables on the species diversity of macrobenthos e.g. reduced discharge (Dewson *et al.*, 2007) or land-use type (Sandin *et al.*, 2006).

2. Menhinick's index of diversity

Menhinicks index of diversity for benthos varied from a minimum of 0.553 in December, 2009 to a maximum of 0.786 in July, 2009 in Medical Pond, from 0.494 in January, 2010 to 0.723 in June, 2009 in Laldiggi Pond and from 0.477 in January, 2010 to 0.7048 in July, 2009 in Chautal Pond (Tables–9, 10, 11). Statistically benthos density showed negative and significant correlation with Menhinicks index in all the selected water bodies (Medical Pond: r = -0.983; Laldiggi Pond: r = -0.982 and Chautal Pond: r = -0.931) (Table – 8).

3. Species Evenness

Monthly species Evenness of benthos in all the three ponds are given in Tables-9,10,11. In the present study, species evenness values varied from a minimum of 0.644 in June, 2009 to a maximum of 0.726 in February, 2009 in Medical Pond, 0.533 in October, 2009 to 0.668 in January, 2010 in Laldiggi Pond and from 0.544 in February, 2009 to 0.703 in August, 2009 in Chautal Pond. The results are similar to the finding of Bu-Olayan *et al.* (2005).

Correlation between species evenness and some Physico-chemical parameters were also determined. Species evenness showed positive correlation with PO_4-P in two ponds and negative correlation in one of the ponds (Medical Pond: r = 0.507; Laldiggi Pond: r = -0.184; Chautal Pond: r = 0.041) (Table – 8).

When the evenness value is getting closer to 1, it means that the individuals are distributed equally (Pielou, 1975). The values of species evenness (Tables-9, 10, 11) indicated that distribution of genera in benthos community was somewhat even throughout the study in all the selected water bodies.

4. Percentage similarity

The Sorenson's index values (% species similarity) for benthic community in all the three ponds are given Tables-12, 13, 14. Similarity index between different months of the recorded benthic groups is depicted in dendrogram and MDS (Fig. 29, 30, 31). The highest similarity 91.67% was recorded in April, 2009 – August, 2009 in Medical Pond followed by 90.49 in July, 2009 – September, 2009 in Laldiggi Pond and 90.12 in February, 2009 – April, 2009 in Chautal Pond. The lowest similarity was 75.96 in March, 2009- January, 2010 in Chautal Pond followed by 78.59 in October, 2009 - January, 2010 in Laldiggi Pond and 79.92 in July, 2009 – December, 2009 in Medical Pond. Overall high Similarity index values suggest that most of the species in these ponds were common during the course of study. This has resulted in overlapping of faunal grouping and predictability of community composition.

According to Wilham (1970) a high value of diversity index (H) suggests a more healthy ecosystem, while a low value suggests a less healthy or degraded ecosystem. Elber and Schanz (1989) also reported that high diversity index is recorded in oligotrophic lakes while low is recorded in eutrophic lakes. From this point of view, diversity should decrease from oligotrophy towards eutrophy. The Shannon – Weiner diversity index proposed as diversity index > 4 is clean water; between 3-4 is mildly polluted water and < 2 is heavily polluted water (Shekhar *et al.*, 2008). Since, the Shannon-Weiner diversity index in the present study ranged between 2.938 – 3.295 in the selected water bodies; they can be considered as moderately polluted. Moreover, diversity and evenness followed the same trend in all the three selected water bodies. High diversity was always associated with high evenness (Ismail and Dorgham, 2003). Low diversity values were strongly affected by the most abundant species. Diversity was reduced to minimal levels by competitive exclusion or some other biotic interaction that can result in steady state assemblage (Naselli- Flores *et al.*, 2003; Rojo and Alvarez-Cobeles, 2003). Shannon-Wiener's index is maximum when all the species in a sample are equally abundant and decreased towards zero as the relative abundance of species diverse away from the evenness (Ismail and Dorgham, 2003).

Canonical correspondence analysis (CCA): The data of benthic community and water and sediment quality variables were drawn up in the form of one matrix and were analysed by canonical correspondence analysis (CCA) using PAST program, version (2.10) by Hammer and Harper (2001), separately in Medical Pond, Laldiggi Pond and Chautal Pond. CCA diagram was performed to determine relationships between 20 environmental variables and 10 groups of benthos. It is a non-linear technique used to relate variations in the environmental factors. Benthic data were log transformed to approach the assumed condition of normality and homoscedasticity of the data to standardize the data sets. The constrained ordination axis corresponds to the direction of the greatest variability of the data set that can be explained by the variables (Leps and Smilauer, 1999). In graph, environmental factors are indicated by the length of arrow, length of line represents the degree of relationship between benthic groups and environmental factors, the angle between arrow shaft and ordination axis indicates the degree of correlation between environmental factors. In addition the analysis make vertical lines connecting a particular group with the line of environmental factors, closer the connecting point on the line of environmental factors to arrow shows stronger positive correlation. Distribution pattern of groups in benthic community are represented by points, points of group and environmental factors indicates the distribution of groups and characteristics of benthic community variance along the gradient direction of each environmental factor.

Result and discussion

The eigen value, value of p and Cumulative percentage variance of groups-environment relation of axes 1-4 are given the table below respective figures 35, 36, 37.

In Medical Pond total Trichoptera and Hemiptera showed positive correlation with Dissolved oxygen whereas Diptera showed high positive correlation with Clay composition and Alkalinity. Copepoda showed high positive correlation with Clay, Sand, Chloride, pH and Mg. Other groups like Rotifera, Oligochaeta and Ephemeroptera showed high negative correlation with Water temperature, Nitrate, Hardness, TDS, % Organic matter, TS and Conductivity and Cladocera, Coleoptera and Ostracoda showed high positive correlation with Transparency, TSS, depth and Composition of Silt. CCA analysis indicates that, in Medical Pond important factors affecting benthos distribution are Water temperature, Dissolved oxygen, Nitrate, Phosphate, Alkalinity, Calcium, Magnesium, Transparency, Chloride, Depth, Total dissolved solids, Total suspended solids, Total solids, % Organic matter, Composition of Silt and Clay. However, pH, Hardness, Conductivity and composition of Sand have a lesser influences on the distribution of the benthic species (Fig. 35).

In Laldiggi Pond Diptera showed high positive correlation with Depth. Rotifera, Ephemeroptera and Oligochaeta showed high positive correlation with TSS, Organic matter, whereas Ephemeroptera and Oligochaeta showed high negative correlation with Clay, TS, Water temperature, Nitrate and Phosphate. Cladocera showed high negative correlation with Chloride. Ostracoda, Hemiptera and Copepoda showed high positive correlation with Calcium and Dissolved oxygen. In this Pond important factors affecting benthos distribution are Water temperature, Dissolved oxygen, Nitrate, Phosphate, Alkalinity, pH, Hardness, Conductivity, Magnesium, Transparency, Chloride, Depth, Total dissolved solids, Total suspended solids and Total solids which considered the most important factors affecting on benthos distribution. However, Calcium, composition of Silt and Sand have a lesser influence on the distribution of the benthic species (Fig. 36).

In Chautal Pond total Ostracoda showed positive correlation with Depth. Coleoptera and Diptera showed high positive correlation with depth and Organic matter. Ephemeroptera, Copepoda, Hemiptera showed positive correlation with Dissolved oxygen, Alkalinity and Composition of Silt. Trichoptera showed high positive correlation with Nitrate. Rotifera showed high negative correlation with Phosphate, Conductivity and Magnesium. Oligochaetes showed high positive correlation with TS and Nitrate. Trichoptera showed high correlation with Nitrate. In this Pond the important factors affecting benthos distribution are Water temperature, Dissolved oxygen, Nitrate, Silt, Sand, Phosphate, Alkalinity, pH, Hardness, Conductivity, Calcium, Magnesium, Depth, Total suspended solids and composition of Clay. However, Chloride, Total dissolved solids, Total solids, % organic matter, composition of Clay and silt have a lesser influence of the distribution of benthic species (Fig. 37).

Tables

Table - 1 (a)

Monthly variation in Air and Water temperature, Transparency, D.O., NO_3-N, PO_4-P, Depth, Hydroxide, Carbonate and Bicarbonate in Medical Pond from February 2009 to January 2010

Months	Air Temp. (°C)	Water Temp. (°C)	Transparency (cm)	D.O. (mg/L)	NO_3-N (mg/L)	PO_4-P (mg/L)	Depth (cm)	Hydroxide (OH^-) (mg/L)	Carbonate CO_3^{--})	Bi-carbonate (HCO_3^{-})
Feb.,09	22	19	42.50	6.0	0.056	0.460	73	90	260	-
Mar.	28	25	45.00	5.8	0.131	0.419	70	50	130	-
Apr.	30	27	36.00	4.0	0.125	0.425	60	-	220	100
May	35	32	21.00	4.0	0.140	0.867	46	-	480	110
Jun.	34	31	17.50	4.8	0.170	1.040	41	-	500	80
Jul.	36	34	22.00	3.6	0.156	0.761	152	-	380	100
Aug.	33	31	17.60	5.0	0.195	0.867	169	-	160	110
Sep.	32	30	36.00	5.6	0.161	0.695	97	-	200	50
Oct.	25	23	42.50	6.0	0.092	0.620	81	-	100	100
Nov.	22	20	41.25	5.8	0.086	0.586	86	-	220	80
Dec.	16	15	38.75	10.0	0.071	0.459	85	-	140	60
Jan.,10	15	14	42.00	8.0	0.054	0.460	82	-	150	60

Table - 1 (b)

Monthly variation in TS, TDS, TSS, CO_2, Chloride, Conductivity, Hardness, Calcium and Magnesium in Medical Pond from February 2009 to January 2010

Months	TS (mg/L)	TDS (mg/L)	TSS (mg/L)	CO_2	Chloride (mg/L)	Conductivity	Hardness (mg/L)	Calcium (mg/L)	Magnesium (mg/L)
Feb.,09	2100	1720	677	-	326.0	1450	168	56.00	21.09
Mar.	1790	1215	585	-	270.0	803	200	58.51	27.69
Apr.	2270	1510	760	-	397.0	890	260	48.00	32.94
May	1960	1400	560	-	495.0	832	224	64.12	43.51
Jun.	2100	1650	450	-	624.0	955	202	57.71	38.24
Jul.	2800	1880	920	-	298.0	1789	174	56.00	22.41
Aug.	2900	1950	950	-	255.0	1497	186	52.00	23.75
Sep.	2750	2010	740	-	129.0	1621	180	55.31	32.94
Oct.	2160	1300	860	-	166.0	1307	166	52.00	19.77
Nov.	1750	1200	550	-	170.0	1316	150	44.88	29.00
Dec.	1600	920	680	-	156.2	1391	132	36.87	25.05
Jan.,10	1526	1636	490	-	127.0	1450	124	52.10	22.41

Table-1 (c)

Monthly variation in pH, Organic carbon, Organic matter, Alkalinity and Sediment composition in Medical Pond from February to January, 2010

onths	pH		Organic C%	Organic matter (%)	Alkalinity(mg/L)		Sediment composition and type			
	water	sediment	sediment	sediment	water	sediment	Sand (%) (>50 µm)	Silt (%) (>2-50 µm)	Clay (%) (<50 µm)	Sediment type
eb.,09	9.0	9.5	0.961	1.657	350.00	125.00	60.39	19.27	20.34	Sandy clay loam
Mar.	9.1	9.4	1.590	2.742	180.00	103.00	56.75	19.41	23.84	Sandy clay loam
Apr.	9.1	9.0	1.057	1.823	320.00	125.00	61.35	15.93	22.72	Sandy clay loam
May	9.3	9.4	0.516	0.891	590.00	140.30	59.78	11.96	28.26	Sandy clay loam
Jun.	9.3	9.6	1.002	1.728	580.00	228.76	65.72	12.91	22.09	Sandy clay loam
Jul.	9.5	9.0	1.242	2.142	480.00	106.75	57.89	19.19	22.92	Sandy clay loam
Aug.	9.0	9.2	1.146	1.976	270.00	133.00	61.72	17.32	20.96	Sandy clay loam
Sep.	8.7	8.9	2.270	3.914	250.00	118.00	58.82	18.32	22.86	Sandy clay loam
Oct.	8.6	9.0	1.208	2.083	200.00	149.00	62.72	17.47	19.81	Sandy clay loam
Nov.	8.8	9.2	0.889	1.532	300.00	84.55	58.94	18.22	22.84	Sandy clay loam
Dec.	8.7	8.4	1.056	1.821	200.00	154.52	61.24	16.95	21.81	Sandy clay loam
n.,10	8.5	9.5	0.974	1.680	210.00	174.00	57.78	17.36	24.86	Sandy clay loam

Table - 2 (a)

Monthly variation in Air, Water temperature, Transparency, D.O., NO_3-N, PO_4-P, Depth , Hydroxide, Carbonate and Bicarbonate in Laldiggi Pond from February, 2009 to January, 2010

Months	Air Temp. (°C)	Water Temp. (°C)	Transparency (cm)	D.O. (mg/L)	NO_3-N (mg/L)	PO_4-P (mg/L)	Depth	Hydroxide (mg/L)	Carbonate (CO_3^{--})	Bi-carbonate (HCO_3^{-})
Feb.,09	23	20	57.50	6.2	0.092	0.530	119	-	-	309
Mar.	26	23	42.00	5.0	0.091	0.550	113	-	-	360
Apr.	26	24	26.00	4.2	0.122	0.785	95	-	-	560
May	35	32	21.00	3.8	0.157	0.707	74	-	-	430
Jun.	36	33	20.00	4.2	0.198	0.965	57	-	-	465
Jul.	34	31	33.75	4.6	0.167	0.786	133	-	-	390
Aug.	32	31	29.50	4.4	0.153	0.890	145	-	-	230
Sep.	31	32	32.00	3.4	0.175	0.641	149	-	140	20
Oct.	24	22	34.00	3.1	0.123	0.435	132	-	-	145
Nov.	19	18	36.25	6.0	0.161	0.541	127	-	140	60
Dec.	17	15	35.00	7.6	0.122	0.290	129	-	100	200
Jan.,10	15	12	45.00	8.0	0.081	0.226	124	-	160	70

Table - 2 (b)

Monthly variation in TS, TDS, TSS, CO_2, Chloride, Conductivity, Hardness, Calcium and Magnesium in Laldiggi Pond from February, 2009 to January, 2010

Months	TS (mg/L)	TDS (mg/L)	TSS (mg/L)	CO_2	Chloride (mg/L)	Conductivity	Hardness (mg/L)	Ca^{++} (mg/L)	Mg^{++} (mg/L)
Feb.,09	1750	1250	500	22.0	142.0	1308	154	89.77	25.05
Mar.	1860	1300	560	18.0	134.2	1248	116	64.12	29.00
Apr.	2080	1415	665	24.0	142.0	1050	114	60.12	36.92
May	2200	1650	550	22.0	200.0	1021	118	58.51	27.69
Jun.	2840	2200	640	20.0	244.0	978	150	41.60	31.64
Jul.	2970	1850	1120	24.0	156.0	1625	170	48.00	26.37
Aug.	2800	1600	1200	30.0	127.8	1505	164	46.50	29.00
Sep.	2500	1825	675	-	170.4	1334	134	38.47	25.05
Oct.	1820	1310	510	27.0	156.4	1095	140	40.00	25.05
Nov.	1460	1120	340	-	123.5	1377	156	48.00	27.69
Dec.	1400	950	450	-	93.7	1547	112	36.00	23.75
Jan.,10	1530	1000	530	-	99.4	1678	140	52.10	18.46

Table - 2(c)

Monthly variation in pH, Organic carbon, Organic matter, Alkalinity and Sediment composition in Laldiggi Pond from February, 2009 to January, 2010

Months	pH		Organic C%	Organic matter (%)	Alkalinity(mg/L)		Sediment composition			
	water	sediment	sediment	sediment	water	sediment	Sand (%) (>50 μm)	Silt (%) (>2-50 μm)	Clay (%) (<50 μm)	Sediment type
Feb.,09	8.3	8.9	1.229	2.120	309.00	156.38	50.97	19.31	29.72	Sandy clay loam
Mar.	8.4	8.6	1.984	3.421	410.00	140.30	62.80	13.74	23.46	Sandy clay loam
Apr.	8.0	8.4	1.723	2.971	500.00	201.33	51.29	14.36	34.35	Sandy clay loam
May	8.8	8.3	1.138	1.963	430.00	94.55	51.65	12.97	35.38	Sandy clay loam
Jun.	8.1	8.5	2.162	3.728	465.00	116.95	54.78	10.36	34.86	Sandy clay loam
Jul.	8.2	8.0	1.232	2.124	390.00	138.74	53.74	14.08	32.18	Sandy clay loam
Aug.	8.4	8.1	0.846	1.460	230.00	137.25	51.89	12.33	35.78	Sandy clay loam
Sep.	8.8	8.5	2.211	3.813	160.00	73.20	58.95	9.27	31.78	Sandy clay loam
Oct.	8.7	8.9	2.488	4.290	145.00	76.25	56.02	15.03	28.95	Sandy clay loam
Nov.	8.6	8.8	1.020	1.760	200.00	117.00	52.78	12.54	34.68	Sandy clay loam
Dec.	8.9	9.2	1.149	1.982	300.00	148.60	60.00	14.32	25.68	Sandy clay loam
Jan.,10	8.8	8.9	0.766	1.321	230.00	165.80	61.76	10.10	28.14	Sandy clay loam

Table - 3(a)

Monthly variation in Air, Water temperature, Water Colour, Transparency, D.O., NO_3-N, PO_4-P , Depth , Hydroxide, Carbonate and Bicarbonate in Chautal Pond from February 2009 to January 2010

Months	TS (mg/L)	TDS (mg/L)	TSS (mg/L)	CO_2	Chloride (mg/L)	Conductivity	Hardness (mg/L)	Ca^{++} (mg/L)	Mg^{++} (mg/L)
Feb.,09	1618	1223	395	10.0	135.0	1482	100	65.73	26.37
Mar.	1528	965	563	20.0	142.0	1518	164	88.17	23.75
Apr.	2040	1600	440	21.0	156.0	1615	120	67.33	27.69
May	2610	2080	530	18.0	184.0	1691	188	72.14	30.32
Jun.	2030	1203	827	19.0	227.0	1461	196	60.00	34.28
Jul.	2680	2073	810	25.0	198.0	1298	180	64.00	25.05
Aug.	2550	1800	750	45.0	184.6	1358	170	58.51	21.09
Sep.	3050	2135	915	35.0	156.2	1267	116	52.00	22.41
Oct.	2584	1900	684	35.0	156.2	1444	188	62.52	18.46
Nov.	1218	700	518	25.0	142.0	1398	240	72.14	30.32
Dec.	1210	755	455	32.0	149.1	998	150	48.00	22.41
Jan.,10	1440	840	600	35.0	184.6	1206	116	66.53	15.82

Table - 3(b)

Monthly variation in TS, TDS, TSS, CO_2, Chloride, Conductivity, Hardness, Calcium and Magnesium in Chautal Pond from February, 2009 to January, 2010

Months	Air Temp. (°C)	Water Temp. (°C)	Transparency (cm)	D.O. (mg/L)	NO_3-N (mg/L)	PO_4-P (mg/L)	Depth	Hydroxide (mg/L)	Carbonate (CO_3^{--})	Bi-carbonate (HCO_3^{--})
Feb.,09	23	19	42.50	3.4	0.081	0.584	87	-	-	306
Mar.	25	23	47.00	3.2	0.117	0.510	83	-	-	330
Apr.	30	28	36.00	3.9	0.131	0.867	67	-	-	320
May	31	28	26.00	4.8	0.151	0.950	58	-	-	358
Jun.	37	34	25.00	4.0	0.123	0.717	51	-	-	330
Jul.	33	31	30.25	3.0	0.182	0.549	87	-	-	352
Aug.	32	30	32.50	4.2	0.202	0.586	95	-	-	390
Sep.	34	32	26.75	3.8	0.278	0.761	99	-	-	250
Oct.	23	21	45.00	3.4	0.195	0.420	84	-	-	259
Nov.	21	19	36.00	3.6	0.122	0.510	80	-	-	407
Dec.	18	16	41.25	7.4	0.081	0.240	83	-	-	270
Jan.,10	16	13	39.00	8.2	0.051	0.289	85	-	-	356

Table - 3(c)

Monthly variation in pH, Organic carbon, Organic matter, Alkalinity and Sediment composition in Chautal Pond from February, 2009 to January, 2010

Months	pH		Organic C%	Organic matter (%)	Alkalinity(mg/L)		Sediment composition			
	water	sediment	sediment	sediment	water	sediment	Sand (%) (>50 μm)	Silt (%) (>2-50 μm)	Clay (%) (<50 μm)	Sediment type
Feb.,09	8.0	8.5	2.211	3.813	306.00	148.59	4.54	27.72	67.74	clay
Mar.	8.1	8.0	0.636	1.098	330.00	105.90	7.82	20.42	71.76	clay
Apr.	8.5	8.7	1.691	2.917	320.00	140.00	9.12	30.92	59.96	clay
May	7.9	8.5	0.764	1.318	358.00	178.00	5.84	28.68	65.48	clay
Jun.	8.0	8.3	0.669	1.154	330.00	125.00	5.44	27.08	67.48	clay
Jul.	8.3	8.6	1.232	2.124	252.00	149.48	9.96	28.46	61.58	clay
Aug.	8.2	8.5	2.776	4.786	390.00	142.32	6.16	32.00	61.84	clay
Sep.	7.8	7.5	2.918	5.031	250.00	127.59	7.30	31.42	61.28	clay
Oct.	8.2	8.4	2.854	4.921	259.00	126.22	4.34	25.96	69.70	clay
Nov.	8.2	8.0	3.375	5.820	407.00	64.55	7.24	29.28	63.48	clay
Dec.	7.9	8.5	1.883	3.248	270.00	136.30	5.76	30.66	63.58	clay
Jan.,10	8.2	8.3	1.445	2.492	356.00	176.00	9.82	22.42	67.76	clay

Table - 4

Monthly distribution and abundance of Benthos (No/m²) in Medical Pond

Months / Genera	Feb'09	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan'10
CLADOCERA												
Daphnia pulex	128	86	98	136	63	95	129	72	97	112	193	115
Bosmina sp.	152	73	98	61	104	85	66	97	132	145	253	128
Moina micrura	178	329	193	132	123	98	166	227	98	197	186	93
Total	458	488	389	329	290	278	361	396	327	454	632	336
COPEPODA												
Cyclops viridis	75	195	124	82	73	63	105	93	164	93	127	239
Diaptomus sp.	115	98	76	92	95	103	83	61	83	129	92	164
Total	190	293	200	174	168	166	188	154	247	222	219	403
ROTIFERA												
Brachionus calyciflars	72	212	72	58	112	55	45	195	202	151	97	105
B. bidentata	169	84	156	138	151	142	151	201	92	145	226	218
B. angularis	198	92	312	115	201	92	272	84	218	312	156	226
Keratella tropica	175	95	58	86	38	42	27	149	172	175	69	96
K. quadrata	68	73	78	29	115	35	24	47	56	56	85	32
Asplanchna priadonta	72	145	68	92	171	29	129	136	21	99	95	72
Filinia longiseta	173	92	39	91	78	125	58	59	115	63	45	98
Notholca sp.	39	59	67	125	98	91	79	82	75	28	42	139
Hexarthra sp.	83	52	125	68	56	112	98	68	129	72	191	296
Total	1049	904	975	802	1020	723	883	1021	1080	1101	1006	1282
OSTRACODA												
Heterocypris	236	172	126	98	83	45	119	98	205	227	118	175
Stenocypris sp.	61	79	78	87	36	68	82	45	71	86	98	53
Centrocypris	69	52	65	72	23	65	76	33	68	79	98	43
Total	366	303	269	257	142	178	277	176	344	392	314	271
OLIGOCHAETA												
Tubifex	45	47	39	53	49	54	79	87	98	73	89	58
Chaetogaster	39	43	47	42	35	29	48	70	61	73	81	46
Nais	35	43	49	62	69	30	49	63	59	67	79	46
Aelosoma	38	53	65	73	62	53	45	37	62	38	39	45
Total	157	186	200	230	215	166	221	257	280	251	288	195

Genera / Months	Feb'09	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan
DIPTERA												
Chironomus larva	260	270	190	362	459	148	67	98	255	268	424	595
Chironomus pupa	25	59	27	13	28	22	17	19	9	21	37	31
Helius larva	13	25	17	15	24	5	19	13	16	9	7	29
Culex larva	33	153	71	52	14	51	42	216	34	78	194	68
Pentanura	168	91	62	262	128	173	73	93	298	132	217	54
Total	499	598	367	704	653	399	218	439	612	508	879	777
HEMIPTERA												
Notonecta insulata	53	47	110	173	98	63	48	11	37	82	263	198
Coroxid	114	58	68	52	109	45	98	32	72	33	198	131
Belostoma	-	-	-	-	-	-	-	-	-	-	-	-
Hebrus sp.	-	-	-	-	-	-	-	-	-	-	-	-
Sigara	9	3	9	5	3	6	8	23	7	2	4	7
Hesperocorixa	153	95	73	42	59	27	42	96	34	56	87	196
Total	329	203	260	272	269	141	196	162	150	173	552	532
COLEOPTERA												
Hydrophilus	124	83	51	66	72	15	53	53	58	52	73	68
Dytiscus	143	61	96	31	23	27	82	93	193	76	164	162
Berosus	34	194	32	52	34	21	58	65	69	71	90	62
Haliplus	92	23	43	92	71	23	47	74	118	62	45	53
Total	393	361	222	241	200	86	240	285	438	261	372	345
TRICHOPTERA												
Limnephilus larva	3	4	2	4	3	3	5	1	6	5	2	7
Phryganaea larva	3	1	1	2	2	2	2	3	2	4	7	4
Polycentropus larva	3	2	1	1	3	2	2	1	3	1	6	2
Total	9	7	4	7	8	7	9	5	11	10	15	13
EPHEMEROPTERA												
Baetis hiemalis nymph	9	5	1	2	3	2	2	9	4	9	5	7
Caenis nymph	2	3	1	2	2	3	2	2	4	2	3	5
Total	11	8	2	4	5	5	4	11	8	11	8	12
Grand Total	3461	3351	2888	3020	2970	2149	2597	2906	3497	3383	4285	4166

Table - 5

Monthly distribution and abundance of Benthos (No/m²) in Laldiggi Pond

Genera / Months	Feb'09	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan'10
CLADOCERA												
Daphnia pulex	169	186	153	125	136	152	327	149	127	136	312	205
Busmina sp.	160	72	94	75	113	151	145	179	173	113	73	217
Moina micrura	322	319	278	370	228	125	81	92	74	228	329	412
Total	651	577	525	570	477	428	553	420	374	477	714	834
COPEPODA												
Cyclops viridis	269	194	229	272	105	186	125	178	127	163	263	314
Diaptomus sp.	268	319	290	173	195	198	64	92	72	68	297	348
Total	537	513	519	445	300	384	189	270	199	231	560	662
ROTIFERA												
Brachionus calyciflors	418	316	397	224	326	254	275	261	115	129	351	237
B. bidentata	219	184	64	35	59	48	25	73	31	85	97	118
B. angularis	33	28	175	78	65	45	76	27	56	63	97	86
Keratella tropica	149	177	71	58	27	86	96	42	38	96	69	175
K. quadrata	21	75	47	58	27	86	95	42	38	96	69	175
Asplanchna priodonta	45	91	129	77	98	36	25	47	142	271	95	128
Filinia longiseta	33	67	95	29	21	125	228	97	92	71	75	116
Notholca sp.	72	120	156	142	98	126	198	134	311	105	215	186
Hexarthra sp.	35	21	36	75	73	82	228	176	65	87	89	92
Total	1025	1079	1170	776	794	888	1246	899	888	1003	1157	1313
OSTRACODA												
Heterocypris	267	186	121	95	117	120	183	118	52	195	235	372
Stenocypris sp.	73	45	56	52	91	71	65	68	38	72	89	23
Centrocypris	56	92	69	103	73	33	82	78	29	53	97	91
Total	396	323	246	250	281	224	330	264	119	320	421	486
OLIGOCHAETA												
Tubifex	81	53	41	51	67	55	63	74	52	59	75	92
Chaetogaster	43	38	36	55	73	79	37	45	85	49	53	76
Nais	27	75	63	82	77	95	85	78	56	62	53	59
Aelosoma	54	63	57	64	46	48	53	65	49	53	62	59
Total	205	229	197	254	263	277	238	262	242	223	243	286

Months / *Genera*	*Feb'09*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*	*Jan*
DIPTERA												
***Chironomus* larva**	510	481	390	267	98	381	478	282	565	402	385	675
***Chironomus* pupa**	29	14	7	3	19	25	9	31	25	29	41	79
***Helius* larva**	15	28	13	6	15	27	15	11	19	3	11	15
***Culex* larva**	67	45	33	52	38	91	115	145	54	69	45	69
Pentanura	263	113	93	42	18	64	125	198	69	324	126	424
Total	884	681	536	370	188	588	742	667	732	827	608	1262
HEMIPTERA												
Notonecta insulata	197	72	54	126	114	76	98	154	73	61	218	161
Coroxid	72	112	65	93	117	93	65	98	13	76	126	96
Belostoma	9	11	19	5	6	15	12	10	6	21	7	58
Hebrus sp.	17	14	76	7	12	15	34	19	5	67	28	115
Sigara	23	7	3	5	8	9	12	10	3	5	51	27
Hesperocorixa	76	52	124	21	39	52	23	45	43	118	149	103
Total	394	268	341	257	296	260	244	336	143	348	579	560
COLEOPTERA												
Hydrophilus	54	13	47	29	49	56	38	47	53	33	97	118
Dytiscus	35	31	43	24	65	93	58	27	32	74	73	96
Berosus	95	23	38	18	91	27	19	57	53	43	71	81
Haliplus	132	118	94	23	61	42	25	34	47	98	61	166
Total	316	185	222	94	266	218	140	165	185	248	302	461
TRICHOPTERA												
***Limnephilus* larva**	5	3	1	3	5	1	2	3	2	2	6	5
***Phryganaea* larva**	3	3	2	2	3	1	3	4	2	3	4	4
***Polycentropus* larva**	2	1	1	1	2	3	3	2	5	2	3	6
Total	10	7	4	6	10	5	8	9	9	7	13	15
EPHEMEROPTERA												
***Baetis hiemalis* nymph**	2	1	3	2	2	2	3	1	2	4	3	1
***Caenis* nymph**	2	2	1	2	3	2	1	2	2	3	3	4
Total	4	3	4	4	5	4	4	3	4	7	6	5
Grand Total	4422	3865	3764	3026	2880	3276	3694	3295	2895	3691	4602	5884

Table - 6

Monthly distribution and abundance of Benthos (No/m²) in Chautal Pond

Genera / Months	Feb'09	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan'10
CLADOCERA												
Daphnia pulex	215	115	298	276	198	162	129	218	206	237	312	297
Basmina sp.	272	198	291	256	314	165	125	162	271	173	215	292
Moina micrura	217	125	197	298	203	146	75	97	272	172	338	319
Total	704	438	786	830	715	473	329	477	749	582	865	908
COPEPODA												
Cyclops viridis	89	63	54	79	73	97	79	87	95	68	159	186
Diaptomus sp.	73	48	75	92	43	38	83	61	152	89	115	128
Total	162	111	129	171	116	135	162	148	247	157	274	314
ROTIFERA												
Brachionus calyciflora	393	183	193	195	193	73	225	57	372	321	413	516
B. bidentata	495	225	376	63	372	223	82	67	129	223	249	519
B. angularis	133	118	128	95	252	86	173	97	115	129	326	117
Keratella tropica	133	85	149	173	183	67	84	98	54	98	219	112
K. quadrata	86	219	115	196	95	83	82	72	94	28	92	45
Asplanchna priodonta	58	130	95	215	73	135	145	75	87	305	95	67
Filinia langiseta	101	35	98	59	253	215	54	97	83	145	120	225
Notholca sp.	59	72	85	191	95	85	68	63	71	74	53	88
Hexarthra sp.	83	197	87	52	102	153	78	123	101	52	79	38
Total	1541	1264	1326	1239	1618	1120	991	749	1106	1375	1646	1727
OSTRACODA												
Heterocypris	194	325	248	349	141	193	285	318	159	386	433	593
Stenocypris sp.	73	67	56	87	108	72	91	61	73	91	87	75
Centrocypris	42	71	51	108	92	53	31	67	40	76	98	54
Total	309	463	355	544	341	318	407	446	272	553	618	722
OLIGOCHAETA												
Tubifex	87	63	47	65	73	82	92	53	65	43	34	52
Chaetogaster	54	83	63	53	73	95	49	56	53	47	73	86
Nais	39	83	72	92	85	93	83	87	53	63	54	67
Aelosoma	57	62	59	67	64	63	67	57	53	62	63	73
Total	237	291	241	271	295	333	291	253	224	217	224	278

Genera / Months	Feb'09	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan
DIPTERA												
Chironomus larva	690	154	170	450	243	139	197	262	105	238	790	1014
Chironomus pupa	5	2	5	4	30	21	13	22	35	24	43	78
Helius larva	15	18	3	9	7	4	3	9	11	13	17	27
Culex larva	31	59	28	60	87	53	92	105	40	147	93	124
Pentanura	67	29	42	85	195	132	95	63	79	112	97	158
Total	808	262	248	608	562	349	400	461	270	534	1040	1401
HEMIPTERA												
Notonecta Insulata	139	28	85	53	91	11	97	65	43	65	121	186
Coroxid	48	12	50	75	103	58	64	89	127	73	173	97
Belostoma	16	7	13	9	7	15	19	32	27	2	68	87
Hebrus sp.	7	15	9	28	3	7	24	12	19	11	39	19
Sigara	7	2	6	14	47	3	13	8	3	21	15	37
Hesperocorixa	78	17	72	46	33	24	89	43	28	56	148	97
Tatal	295	81	235	225	284	118	306	249	247	228	564	523
COLEOPTERA												
Hydrophilus	17	14	38	98	25	68	79	53	32	67	54	92
Dytiscus	45	9	23	23	21	52	37	64	33	52	87	89
Berosus	98	23	49	51	62	87	56	72	98	43	125	117
Holiplus	173	82	33	31	59	24	67	35	52	65	52	105
Tatal	333	128	143	203	167	231	239	224	215	227	321	403
TRICHOPTERA												
Limnephilus larva	3	2	1	3	3	1	2	1	1	2	5	4
Phryganaea larva	3	4	3	3	2	3	3	2	3	4	2	4
Polycentropus larva	2	3	1	3	3	4	2	1	1	2	2	2
Tatal	8	9	5	9	8	8	7	4	5	8	9	11
EPHEMEROPTERA												
Baetis hiemalis nymph	3	1	2	5	3	2	2	3	2	4	3	3
Caenis nymph	2	1	2	3	2	2	3	2	5	5	4	5
Tatal	5	2	4	8	5	4	5	5	7	9	7	8
Grand Total	4328	3049	3473	4114	3111	3089	3137	3016	3418	3886	5570	6296

Table - 7

Monthly Variations in Species Diversity of different groups in Medical Pond, Laldiggi Pond and Chautal Pond

Groups	Medical Pond	Laldiggi Pond	Chautal Pond
Cladocera	1.08	1.07	1.09
Copepoda	0.688	0.693	0.691
Rotifera	2.139	2.077	2.115
Ostracoda	1.026	0.986	0.85
Oligochaeta	1.382	1.383	1.384
Diptera	1.225	1.083	1.058
Hemiptera	1.188	1.544	1.586
Coleoptera	1.368	1.373	1.369
Trichoptera	1.076	1.095	1.088
Epemeroptera	0.646	0.693	0.692

Table – 8

Statistical brief of various water quality parameters in Medical Pond, Laldiggi Pond and Chautal Pond

Parameters	*Parameters*	*Pond*	*Correlation (r value)*	*Significant at P<0.05*
Air Temperature	*Water Temperature*	*MP*	*0.996*	✓
		LDP	*0.985*	✓
		CP	*0.995*	✓
Water Temperature	*Transparency*	*MP*	*-0.768*	✓
		LDP	*-0.641*	✓
		CP	*-0.745*	✓
	Conductivity	*MP*	*-0.101*	–
		LDP	*-0.415*	–
		CP	*0.375*	–
	DO	*MP*	*-0.853*	✓
		LDP	*-0.811*	✓
		CP	*-0.577*	✓
	TS	*MP*	*0.758*	✓
		LDP	*0.907*	✓
		CP	*0.746*	✓
	Chloride	*MP*	*0.550*	✓
		LDP	*0.778*	✓

Continued

		CP	0.546	✓
	TDS	MP	0.542	✓
		LDP	0.931	✓
		CP	0.689	✓
	TSS	MP	0.353	-
		LDP	0.604	✓
		CP	0.656	✓
	NO_3-N	MP	0.915	✓
		LDP	0.754	✓
		CP	0.686	✓
	PO_4-P	MP	0.730	✓
		LDP	0.875	✓
		CP	0.739	✓
	Cladocera	MP	-0.610	✓
		LDP	-0.647	✓
		CP	-0.503	✓
	Copepod	MP	-0.675	✓
		LDP	-0.543	✓
		CP	-0.745	✓
	Rotifer	MP	-0.769	✓
		LDP	-0.618	✓
		CP	-0.584	✓
	Ostracod	MP	-0.667	✓

Continued

		LDP	-0.595	✓
		CP	-0.552	✓
	Diptera	MP	-0.654	✓
		LDP	-0.716	✓
		CP	-0.655	✓
		MP	-0.712	✓
	Hemiptera	LDP	-0.676	✓
		CP	-0.596	✓
		MP	-0.721	✓
	Coleoptera	LDP	-0.741	✓
		CP	-0.669	✓
	Oligochaeta	MP	-0.187	-
		LDP	-0.180	-
		CP	-0.527	✓
		MP	-0.757	✓
	Trichoptera	LDP	-0.555	✓
		LDP	-0.499	-
	Ephemeroptera	MP	-0.670	✓
		LDP	-0.647	✓
		CP	-0.565	✓
Transparency	DO	MP	0.546	✓
		LDP	0.578	✓
		CP	0.095	-
	TDS	MP	-0.472	-

Continued

		LDP	-0.610	✓
		CP	-0.499	-
	TSS	MP	-0.187	-
		LDP	-0.262	-
		CP	-0.569	✓
Conductivity	TDS	MP	0.474	-
		LDP	-0.397	-
		CP	0.327	-
pH	Total alkalinity	MP	0.783	✓
		LDP	-0.635	✓
		CP	0.203	-
	Depth	MP	0.743	✓
		LDP	0.707	✓
		CP	0.541	✓
	PO_4- P	MP	0.492	-
		LDP	-0.694	✓
		CP	-0.037	-
TDS	Total alkalinity	MP	0.265	-
		LDP	0.358	-
		CP	-0.388	-
	Hardness	MP	0.168	-
		LDP	0.318	-
		CP	-0.053	-
	D.O.	MP	0.510	✓
		LDP	-0.631	✓
		CP	-0.446	-

Continued

	NO_3	MP	0.528	✓
		LDP	0.781	✓
		CP	0.809	✓
	Cladocera	MP	-0.622	✓
		LDP	-0.604	✓
		CP	-0.298	-
	Copepod	MP	-0.306	-
		LDP	-0.473	-
		CP	-0.292	-
	Oligochaeta	MP	-0.457	-
		LDP	0.318	-
		CP	0.309	-
	Rotifer	MP	-0.171	-
		LDP	-0.646	✓
		CP	-0.782	✓
	Ostracod	MP	-0.572	✓
		LDP	-0.516	✓
		CP	-0.493	-
	Diptera	MP	-0.538	✓
		LDP	-0.705	✓
		CP	-0.535	✓
	Hemiptera	MP	-0.350	
		LDP	-0.552	✓

Continued

		CP	-0.450	-
	Coleoptera	*MP*	-0.463	
		LDP	-0.481	-
		CP	-0.328	-
	Trichoptera	*MP*	-0.493	-
		LDP	-0.380	-
		CP	-0.596	✓
	Ephemeroptera	*MP*	-0.079	-
		LDP	-0.443	-
		CP	-0.247	-
Total alkalinity	*Hardness*	*MP*	0.447	-
		LDP	-0.309	-
		CP	0.365	-
NO_3- N	*Cladocera*	*MP*	-0.464	-
		LDP	-0.662	✓
		CP	-0.601	✓
	Copepod	*MP*	-0.573	✓
		LDP	-0.697	✓
		CP	-0.366	-
	Oligochaeta	*MP*	-0.057	-
		LDP	0.295	-
		CP	0.143	-
	Rotifera	*MP*	-0.654	✓
		LDP	-0.632	✓

Continued

		CP	-0.952	✓
	Ostracod	MP	-0.684	✓
		LDP	-0.481	-
		CP	-0.397	-
	Diptera	MP	-0.570	
		LDP	-0.676	
		CP	-0.643	
Diversity	Water temperature	MP	-0.041	-
		LDP	-0.246	-
		CP	0.544	✓
	NO_3	MP	-0.022	-
		LDP	0.197	-
		CP	0.751	✓
	D.O.	MP	0.019	-
		LDP	0.542	✓
		CP	-0.206	-
	PO_4	MP	-0.463	-
		LDP	-0.166	-
		CP	0.042	-
	Cladocera	MP	0.464	-
		LDP	0.259	-
		CP	-0.542	✓
	Copepoda	MP	-0.267	-
		LDP	0.213	-
		CP	-0.126	-

Continued

	Rotifera	*MP*	*-0.172*	-
		LDP	*0.243*	-
		CP	*-0.623*	✓
	Ostracoda	*MP*	*0.282*	-
		LDP	*0.495*	-
		CP	*-0.174*	-
	Oligochaeta	*MP*	*0.114*	-
		LDP	*0.403*	-
		CP	*0.223*	-
	Diptera	*MP*	*-0.534*	✓
		LDP	*0.261*	-
		CP	*-0.378*	-
	Hemiptera	*MP*	*-0.188*	-
		LDP	*0.675*	✓
		CP	*-0.088*	-
	Coleoptera	*MP*	*0.184*	-
		LDP	*0.591*	✓
		CP	*-0.201*	-
	Trichoptera	*MP*	*-0.268*	-
		LDP	*0.354*	-
		CP	*-0.481*	-
	Ephemeroptera	*MP*	*0.165*	-
		LDP	*0.441*	-
		CP	*-0.019*	-
Diversity	*Benthic fauna*	*MP*	*-0.223*	-
		LDP	*0.344*	-

Continued

		CP	-0.534	✓
Eveness	NO_3	MP	-0.019	-
		LDP	0.193	-
		CP	0.757	✓
	D.O.	MP	0.016	-
		LDP	0.546	✓
		CP	-0.213	-
	PO_4	MP	-0.451	-
		LDP	-0.184	-
		CP	0.041	-
	Benthic fauna	MP	-0.227	-
		LDP	0.339	-
		CP	-0.536	✓
Menhinick's index	Benthic fauna	MP	-0.983	✓
		LDP	-0.982	✓
		CP	-0.931	✓
Organic matter	Benthic fauna	MP	-0.198	-
		LDP	-0.586	✓
		CP	-0.343	-
	Diptera	MP	-0.570	✓
		LDP	-0.676	✓
		CP	-0.643	✓
	Hemiptera	MP	-0.604	✓
		LDP	-0.398	
				-

Continued

		LDP	-0.085	-
		CP	0.159	-
		MP	-0.198	-
	Diptera	LDP	-0.696	✓
		CP	-0.510	✓
	Hemiptera	MP	-0.384	-
		LDP	-0.603	✓
		CP	-0.536	✓
	Coleoptera	MP	-0.571	✓
		LDP	-0.581	✓
		CP	-0.608	✓
		MP	-0.235	-
	Trichoptera	LDP	-0.634	✓
		CP	-0.422	-

Continued

		CP	-0.465	
	Coleoptera	MP	-0.659	✓
		LDP	-0.500	✓
		CP	-0.431	-
	Trichoptera	MP	-0.622	✓
		LDP	-0.362	-
		CP	-0.767	✓
	Ephemeroptera	MP	-0.632	✓
		LDP	0.020	-
		CP	-0.263	-
PO_4- P	Cladocera	MP	-0.625	✓
		LDP	-0.567	✓
		CP	-0.128	
	Copepod	MP	-0.552	✓
		LDP	-0.495	
		CP	-0.690	✓
	Rotifer	MP	-0.409	-
		LDP	-0.401	-
		CP	-0.406	-
	Ostracod	MP	-0.615	✓
		LDP	-0.472	-
		CP	-0.385	-
	Oligochaeta	MP	0.087	-

Continued

Parameters	Parameters	Pond	Correlation (r value)	Significant at P<0.05
	Ephemeroptera	MP	-0.435	-
				-
		LDP	-0.321	
				-
		CP	-0.273	
D.O.	*Cladocera*	MP	0.698	✓
		LDP	0.854	✓
		CP	0.627	✓
	Copepod	MP	0.523	✓
		LDP	0.662	✓
		CP	0.817	✓
	Rotifer	MP	0.599	✓
		LDP	0.631	✓
		CP	0.566	✓
	Ostracoda	MP	0.387	-
		LDP	0.900	✓
		CP	0.817	✓
	Oligochaeta	MP	0.435	-
		LDP	0.678	✓
		CP	0.133	-
	Diptera	MP	0.647	✓
		LDP	0.593	✓
		CP	0.876	✓
		MP	0.772	✓

Continued

	Hemiptera	*LDP*	*0.889*	✓
		CP	*0.860*	✓
		MP	*0.667*	✓
	Coleoptera	*LDP*	*0.825*	✓
		CP	*0.693*	✓
		MP	*0.846*	✓
	Trichoptera	*LDP*	*0.642*	✓
		CP	*0.560*	✓
	Ephemeroptera	*MP*	*0.586*	✓
		LDP	*0.783*	✓
		CP	*0.761*	✓
	Chloride	*MP*	*-0.582*	✓
		LDP	*-0.683*	✓
		CP	*-0.506*	✓

Table – 9

Monthly variation in Species Diversity and Species Evenness of benthos in Medical Pond

Months	Species Diversity	Menhinick Index	Species Evenness
Feb, 09	3.236	0.6089	0.7265
Mar	3.205	0.6221	0.7046
Apr	3.216	0.6751	0.7121
May	3.169	0.6626	0.6798
Jun	3.115	0.6668	0.644
Jul	3.205	0.7865	0.7044
Aug	3.224	0.718	0.7179
Sep	3.217	0.68	0.7132
Oct	3.178	0.6171	0.6857
Nov	3.192	0.6254	0.6951
Dec	3.203	0.5537	0.7031
Jan, 10	3.141	0.5554	0.6606

Table - 10

Monthly variation in Species Diversity and Species Evenness of benthos in Laldiggi Pond

Months	Species Diversity	Menhinick Index	Species Evenness
Feb, 09	3.075	0.5697	0.5853
Mar	3.058	0.6138	0.5756
Apr	3.119	0.6195	0.6117
May	3.038	0.7028	0.564
Jun	3.183	0.7233	0.6521
Jul	3.192	0.6756	0.6581
Aug	3.082	0.6294	0.5893
Sep	3.203	0.6718	0.6653
Oct	2.983	0.7183	0.5337
Nov	3.198	0.6283	0.6619
Dec	3.206	0.5604	0.6667
Jan, 10	3.208	0.4945	0.6681

Table - 11

Monthly variation in Species Diversity and Species Evenness of benthos in Chautal Pond

Months	Species Diversity	Menhinick Index	Species Evenness
Feb, 09	3.002	0.5711	0.544
Mar	3.063	0.7045	0.5784
Apr	3.088	0.6509	0.593
May	3.107	0.5997	0.6002
Jun	3.173	0.599	0.6455
Jul	3.205	0.7048	0.6661
Aug	3.259	0.6936	0.7034
Sep	3.226	0.7039	0.6805
Oct	3.171	0.6587	0.6441
Nov	3.163	0.6105	0.6388
Dec	3.135	0.5062	0.6213
Jan, 10	3.043	0.4774	0.5669

Table - 12

Variation in similarity Index of Benthos between two different months in Medical Pond

	Feb'09	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan'10
Feb'09												
Mar	85.502											
Apr	88.399	86.95										
May	87.128	85.60	88.008									
Jun	86.786	85.20	87.665	89.296								
Jul	84.901	82.88	86.796	88.799	85.532							
Aug	86.718	85.131	91.676	88.745	86.586	86.931						
Sep	84.864	87.486	86.2761	84.536	84.189	82.120	86.982					
Oct	89.111	85.633	86.768	87.250	84.191	84.694	86.158	84.742				
Nov	90.667	87.466	89.854	88.090	86.4296	83.726	88.625	88.765	89.158			
Dec	86.237	84.282	86.828	85.985	84.2466	79.926	84.201	84.050	84.533	87.307		
Jan'10	87.268	84.2839	86.903	85.827	85.4750	80.954	84.7995	82.108	85.951	85.771	87.309	

Table - 13

Variation in similarity Index of Benthos between two different months in Laldiggi Pond

	Feb'09	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan'10
Feb'09												
Mar	89.469											
Apr	86.320	89.471										
May	82.942	87.311	87.100									
Jun	84.632	85.088	86.014	88.410								
Jul	85.076	87.731	87.807	87.680	87.990							
Aug	81.681	84.358	84.225	84.2938	82.136	89.096						
Sep	86.252	85.567	85.321	87.051	87.008	90.497	89.063					
Oct	79.918	81.698	83.826	83.849	83.876	87.607	84.361	86.068				
Nov	85.703	86.318	88.669	83.850	84.528	87.739	85.633	86.629	84.650			
Dec	88.607	88.344	89.0738	86.254	86.475	86.184	84.957	86.078	80.961	86.707		
Jan'10	87.090	84.809	84.168	80.125	79.597	82.975	80.926	82.230	78.595	85.631	88.530	

Table - 14

Variation in similarity Index of Benthos between two different months in Chautal Pond

	Feb'09	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan'10
Feb'09												
Mar	82.522											
Apr	90.124	87.302										
May	84.765	84.913	88.092									
Jun	86.904	83.777	89.387	85.800								
Jul	83.793	86.927	87.167	83.824	87.236							
Aug	85.705	86.075	88.046	88.241	86.045	87.244						
Sep	85.257	85.237	88.261	87.576	86.359	89.395	90.074					
Oct	88.178	84.536	88.484	86.045	86.727	87.611	87.3592	88.055				
Nov	85.751	84.768	87.763	88.338	87.339	86.559	89.4529	88.936	86.69			
Dec	87.337	78.484	84.372	85.542	85.437	80.573	84.3104	84.419	85.720	86.660		
Jan'10	87.054	75.964	82.450	82.520	84.023	79.780	81.160	81.631	82.85	85.555		

Figures

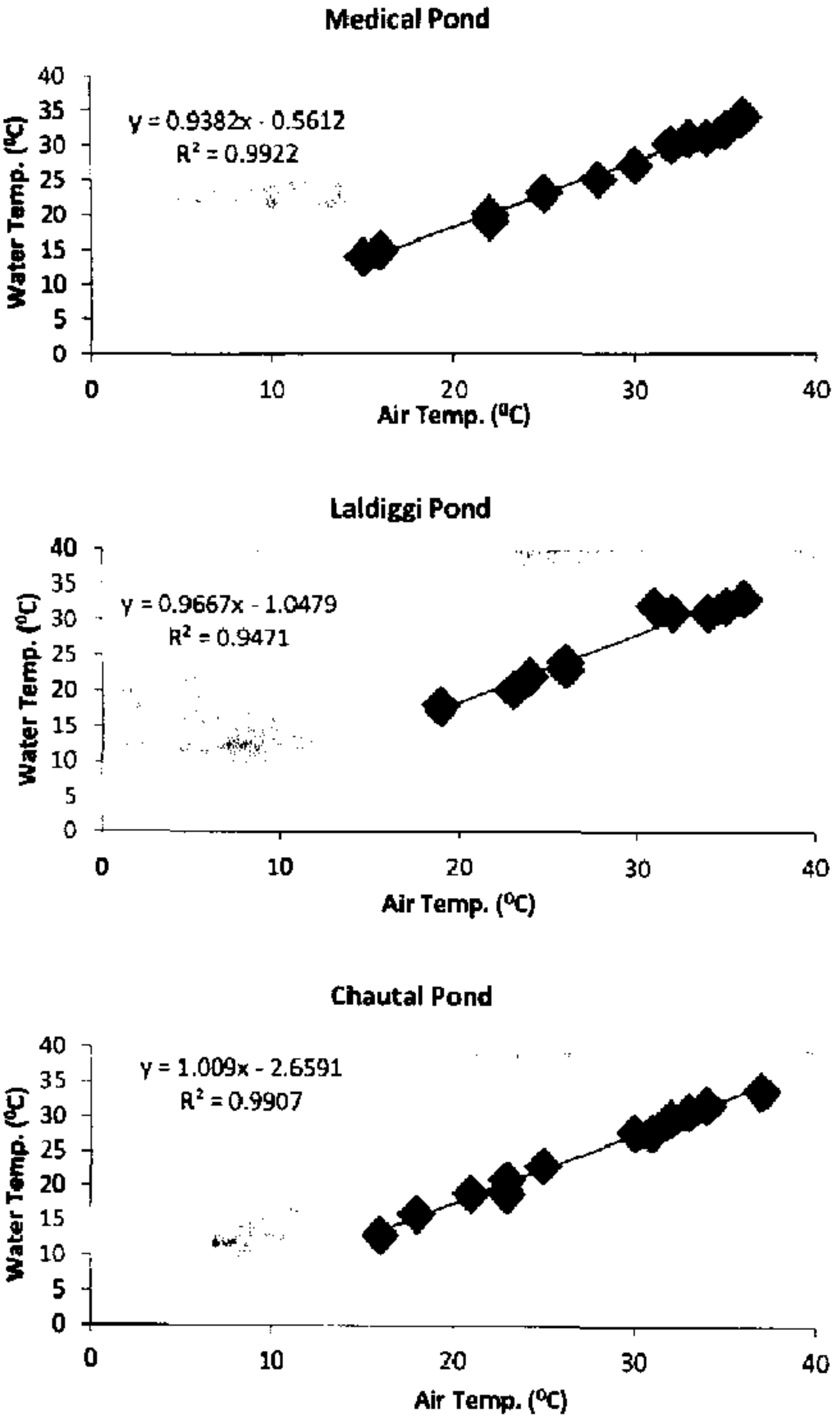
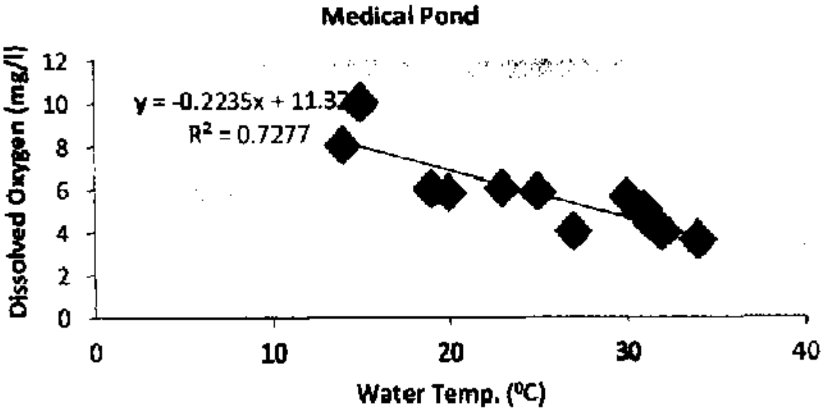
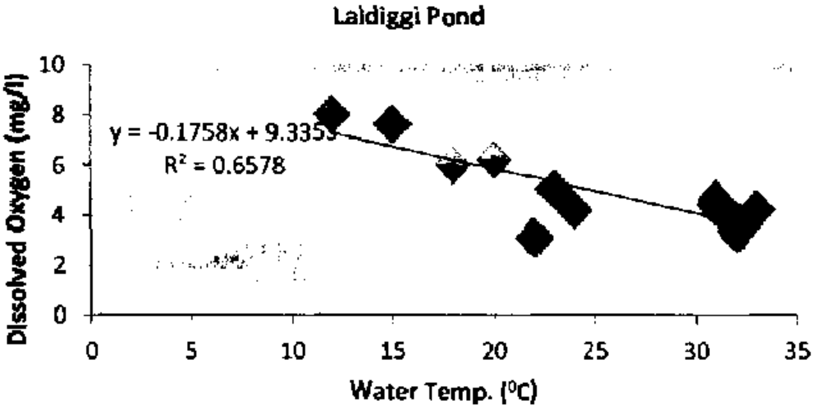


Fig.1- Regression lines showing relationship between Air Temperature (°C) and Water Temperature (°C) in Medical Pond, Laldiggi Pond and Chautal Pond





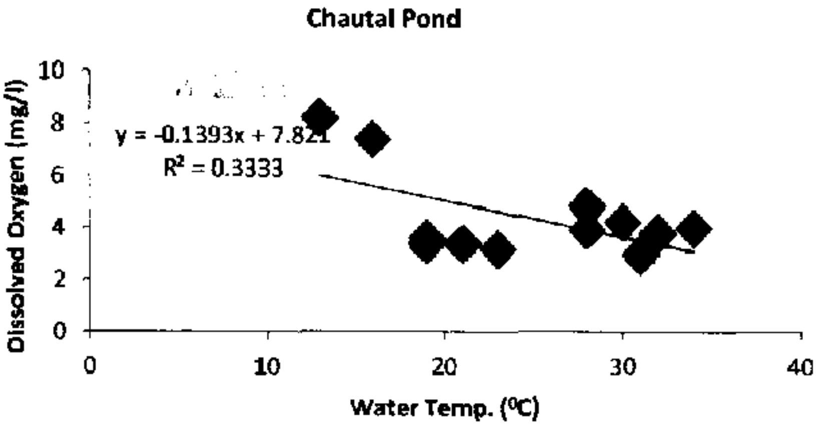
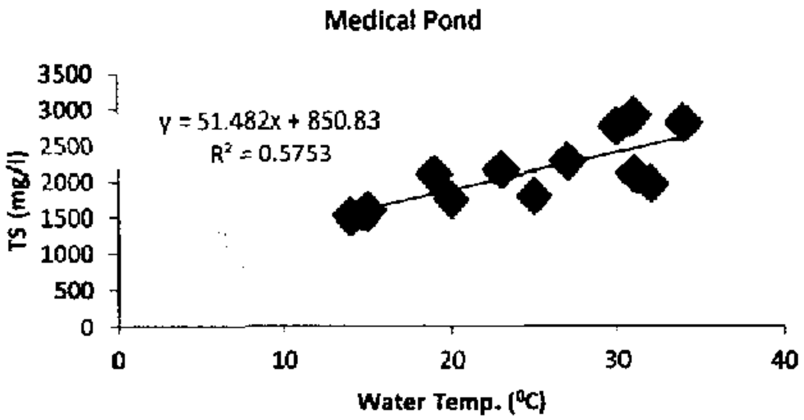
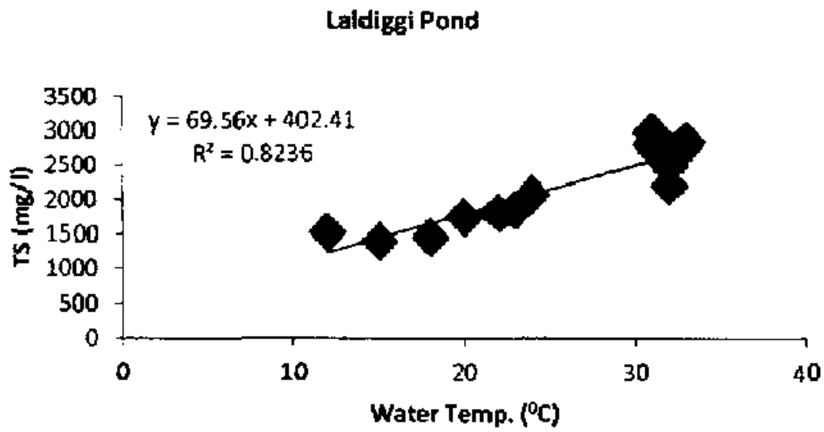


Fig.2- Regression lines showing relationship between Dissolved Oxygen (mg/l) and Water Temperature (°C) in Medical Pond, Laldiggi Pond and Chautal Pond.





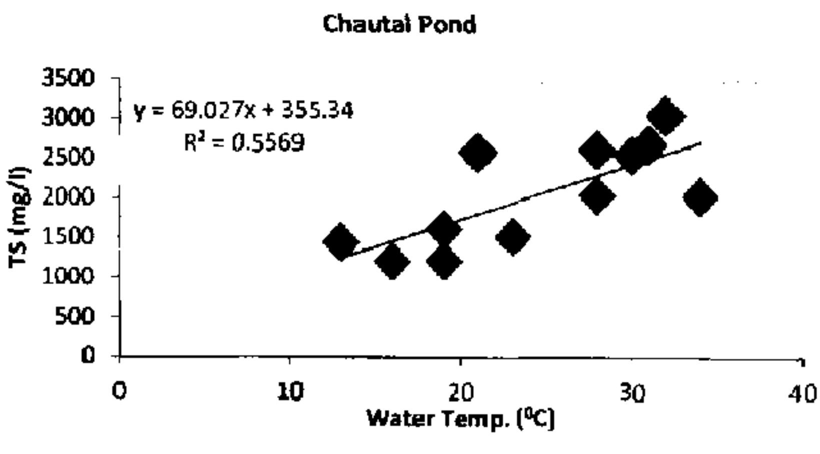
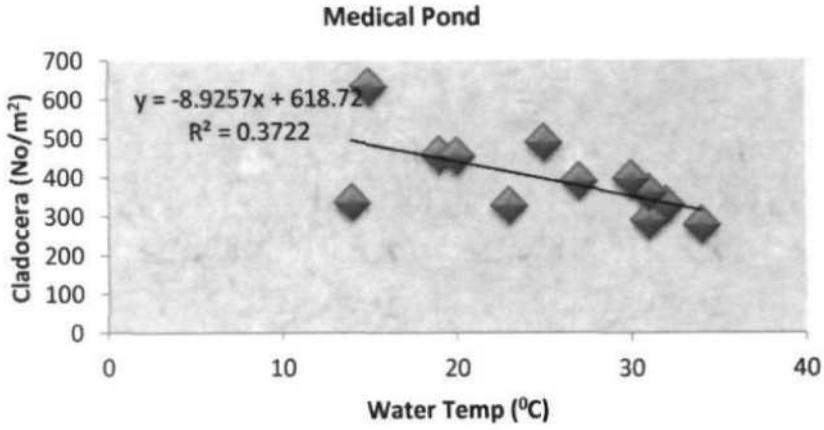
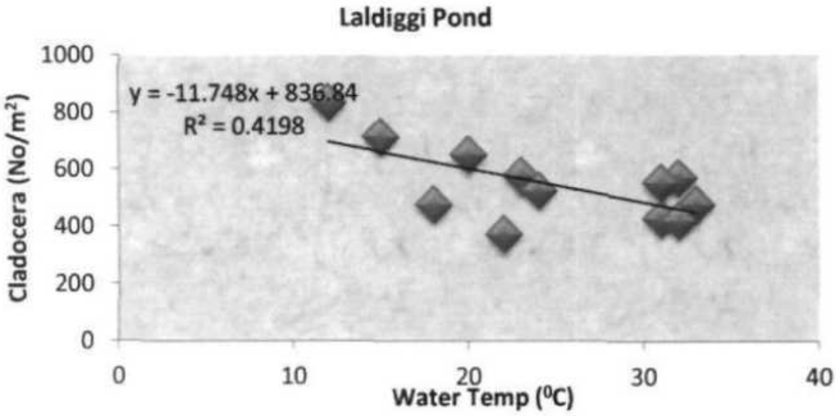


Fig.3- Regression lines showing relationship between T.S (mg/l) and Water Temperature (°C) in Medical Pond, Laldiggi Pond and Chautal Pond





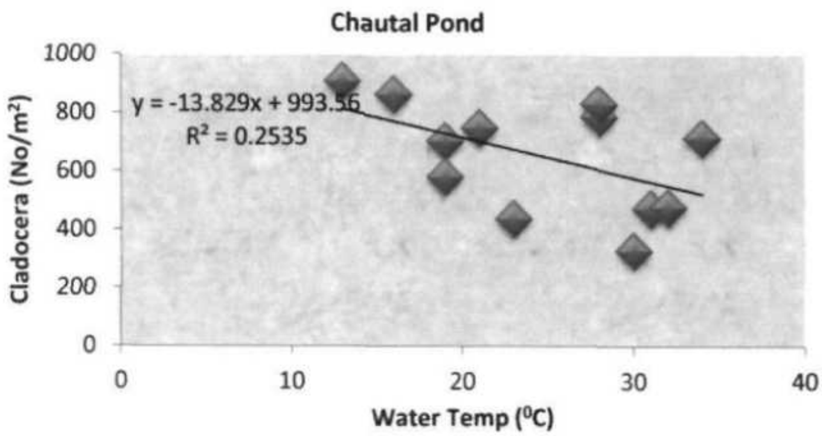


Fig.4- Regression lines showing relationship between Cladocera (No/m²) and Water temperature (°C) in Medical Pond, Laldiggi Pond and Chautal Pond

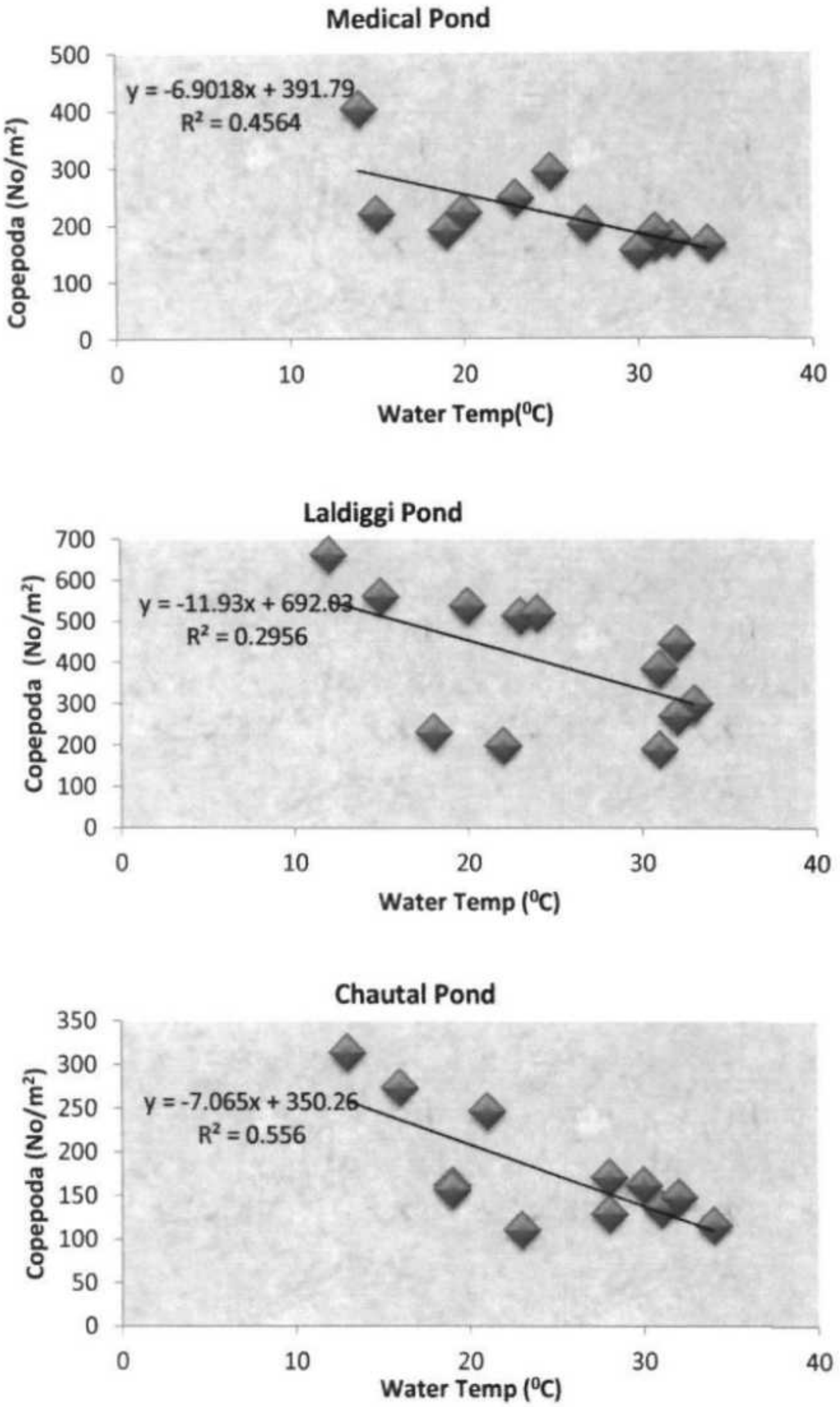


Fig.5- Regression lines showing relationship between Copepoda (No/m^2) and Water temperature (°C) in Medical Pond, Laldiggi Pond and Chautal Pond

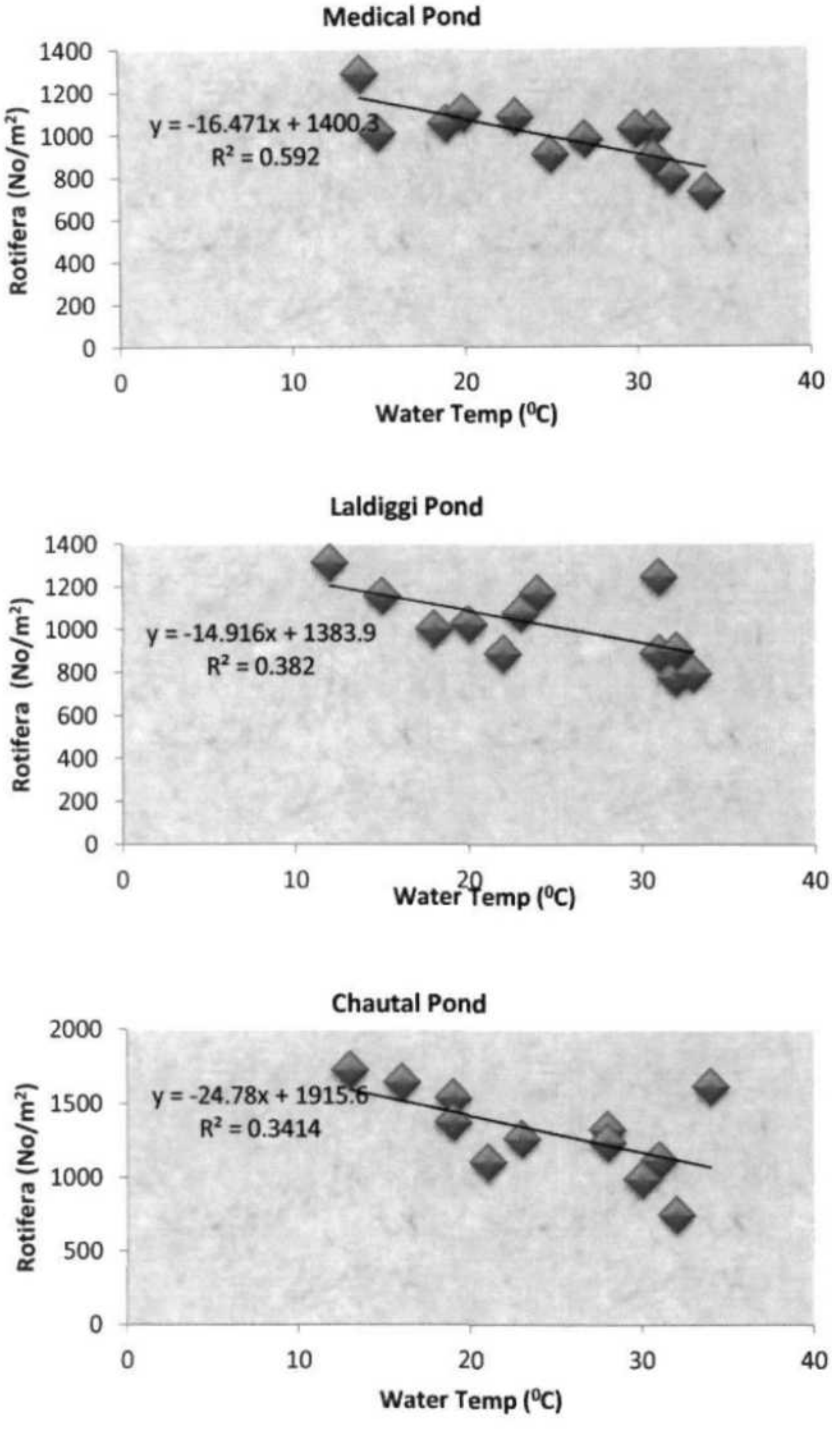
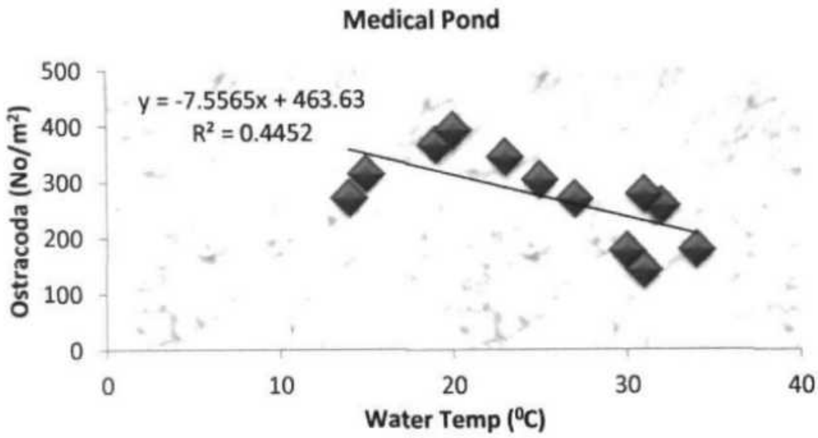
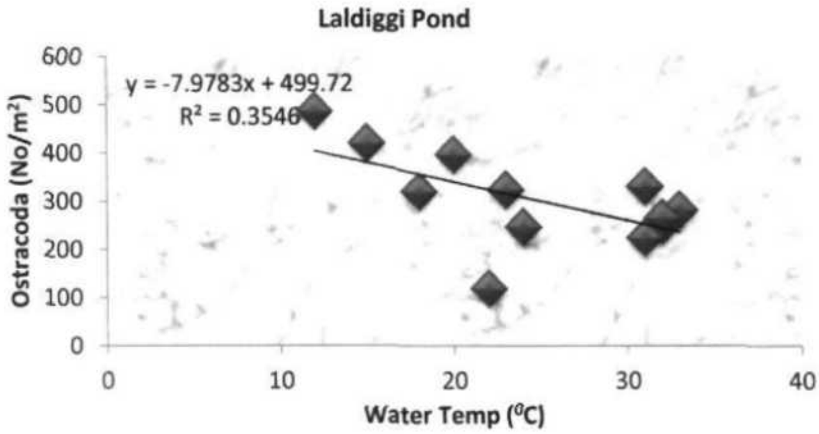


Fig.6- Regression lines showing relatioship between Rotifera (No/m²) and Water temperature (°C) in Medical Pond, Laldiggi Pond and Chautal Pond





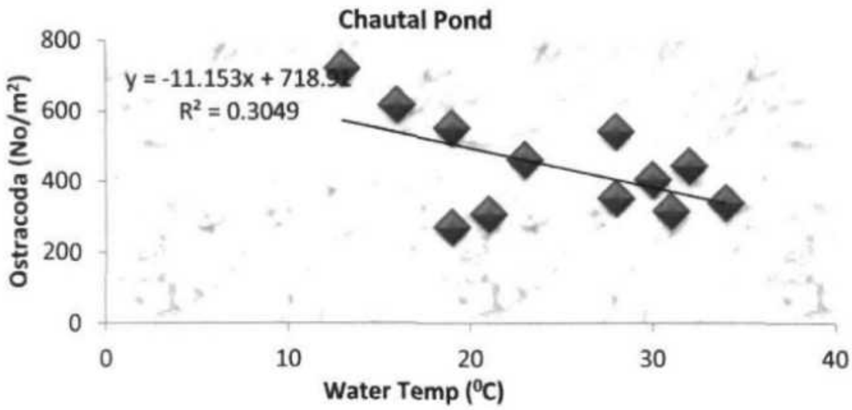
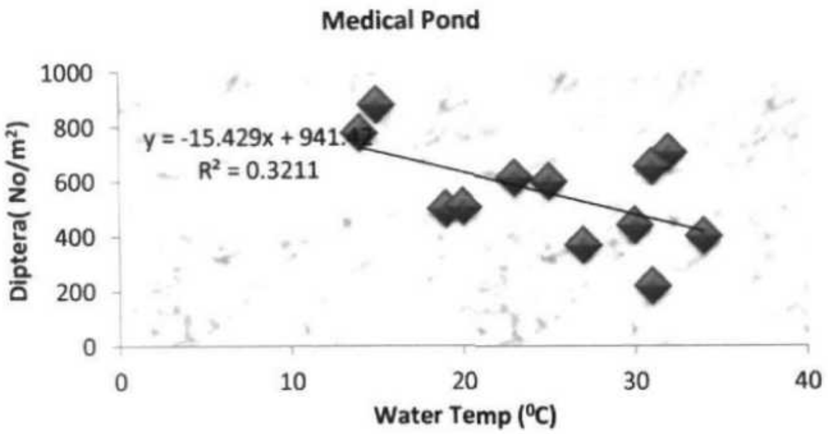
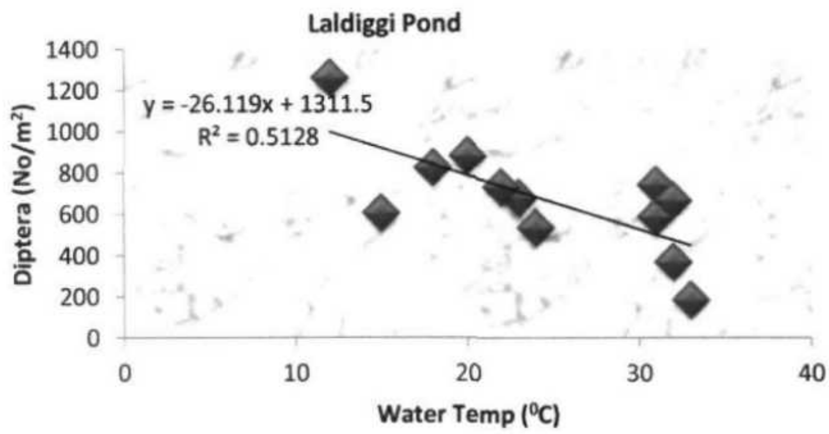


Fig.7- Regression lines showing relatioship between Ostracoda (No/m^2) and Water Temperature (°C) in Medical Pond, Laldiggi Pond and Chautal Pond





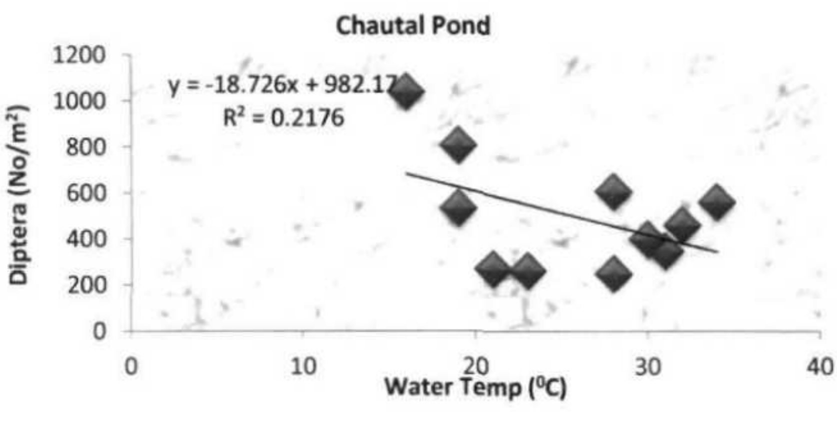


Fig.8- Regression lines showing relatioship between Diptera (No/m²) and Water Temperature (°C) in Medical Pond, Laldiggi Pond and Chautal Pond

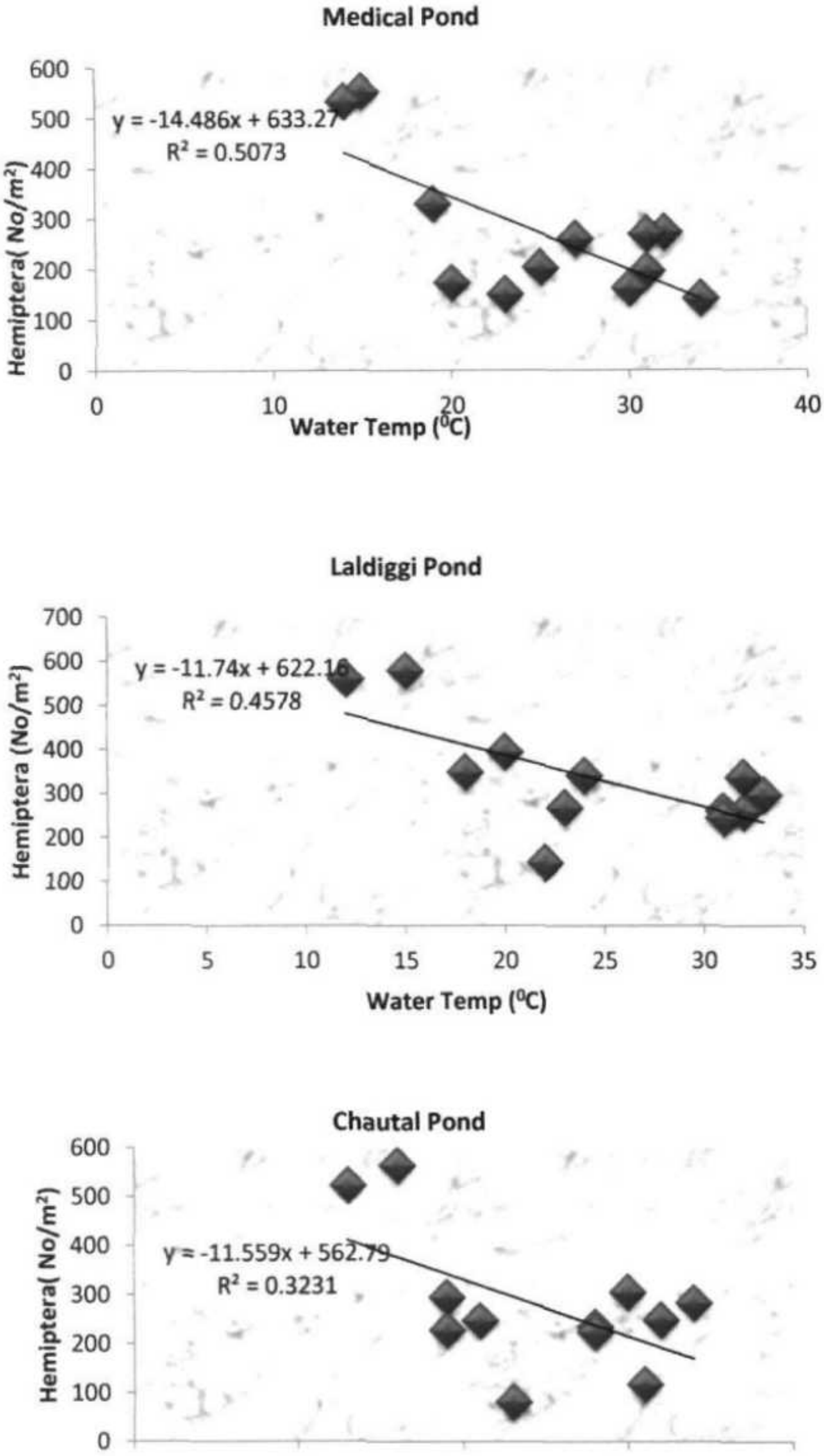
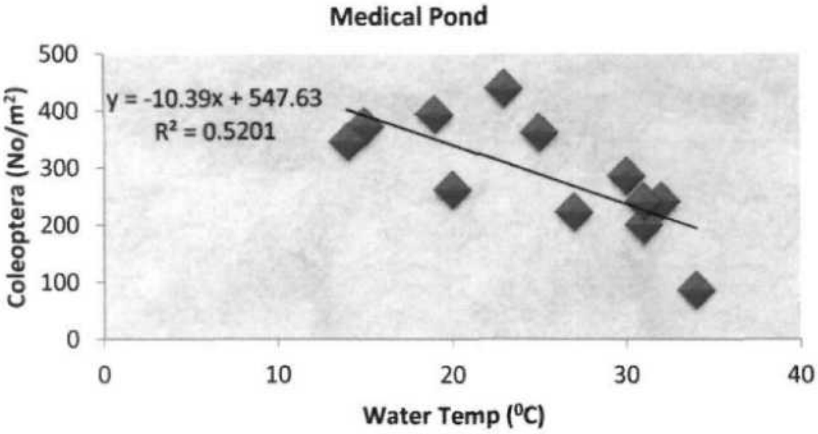
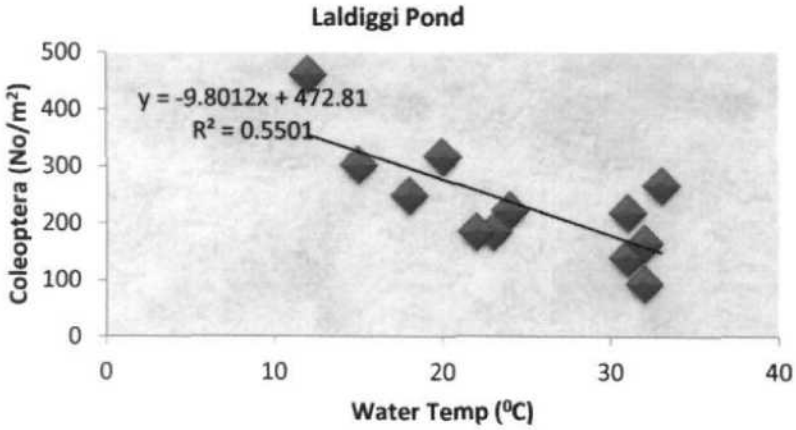


Fig.9- Regression lines showing relationship between Hemiptera (No/m^2) and Water temperature (°C) in Medical Pond, Laldiggi Pond and Chautal Pond





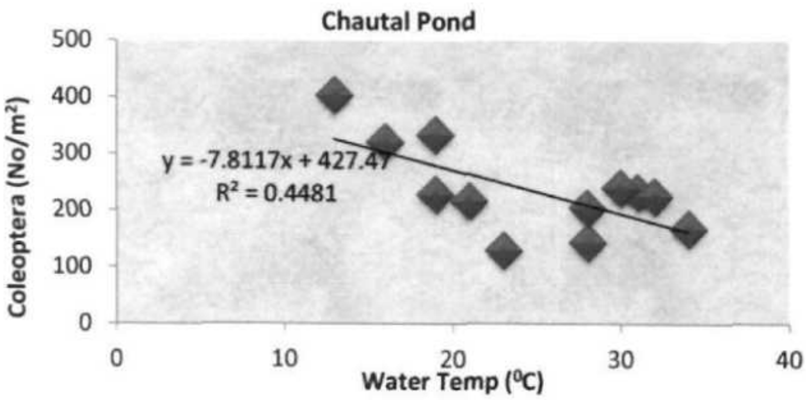
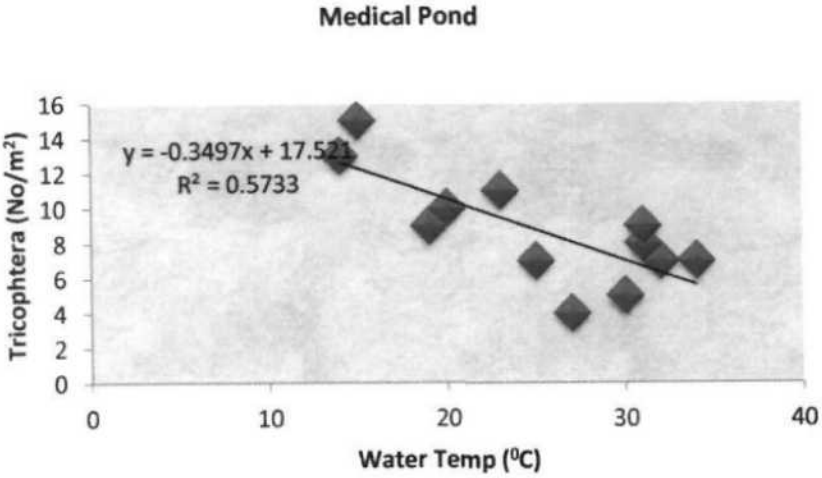
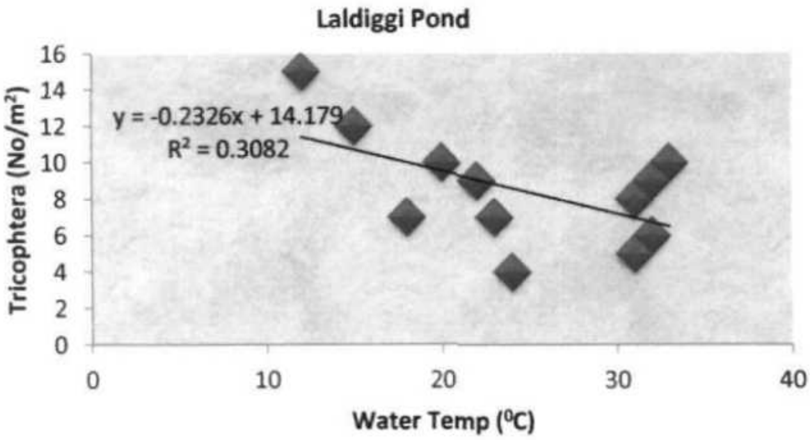


Fig.10- Regression lines showing relationship between Coleoptera (No/m^2) and Water Temperature (°C) in Medical Pond, Laldiggi Pond and Chautal Pond





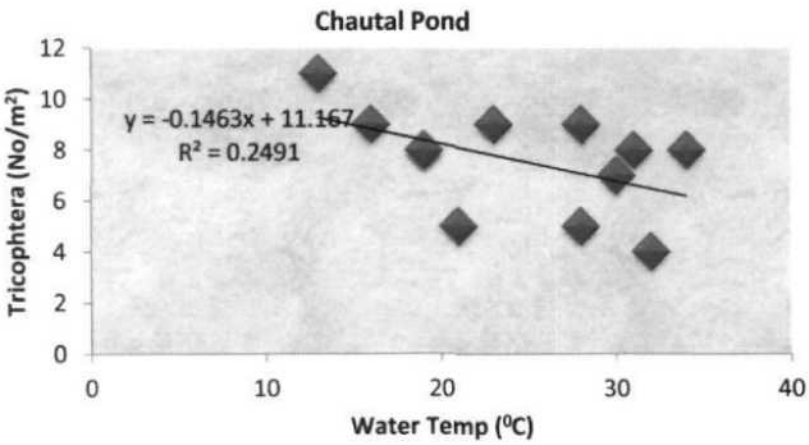
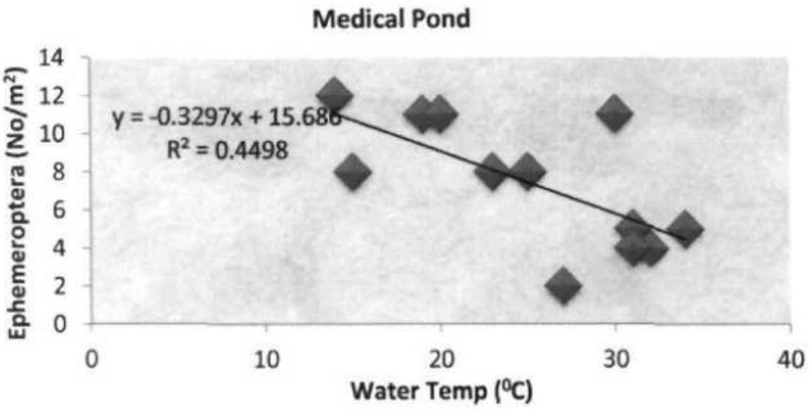
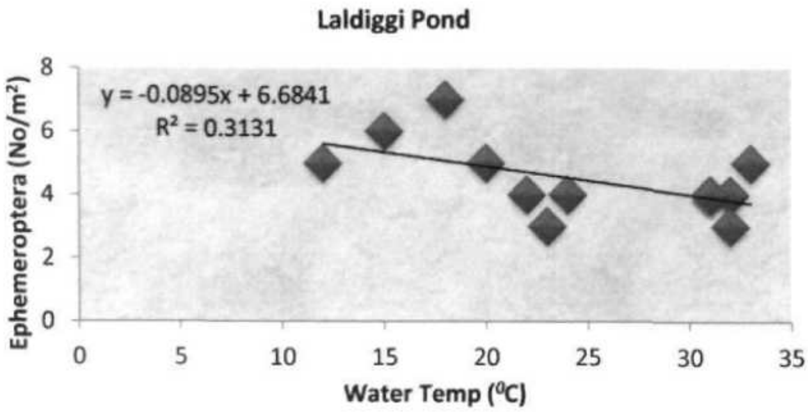


Fig.11- Regression lines showing relationship between Trichoptera (No/m^2) and Water temperature (°C) in Medical Pond, Laldiggi Pond and Chautal Pond





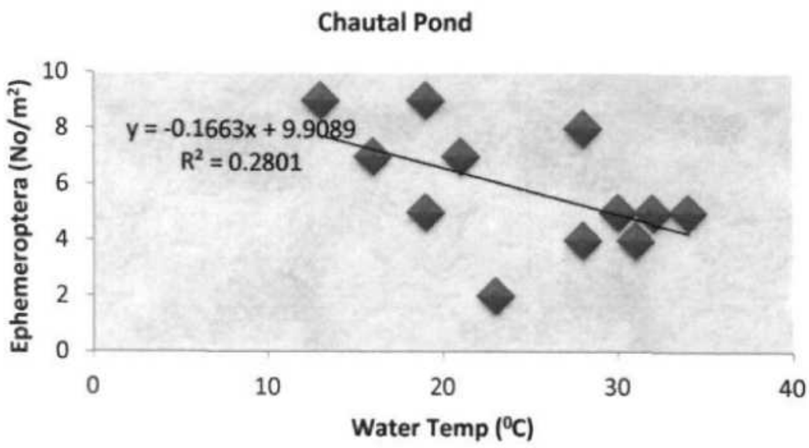


Fig.12- Regression lines showing relationship between Ephemeroptera (No/m²) and Water temperature (°C) in Medical Pond, Laldiggi Pond and Chautal Pond

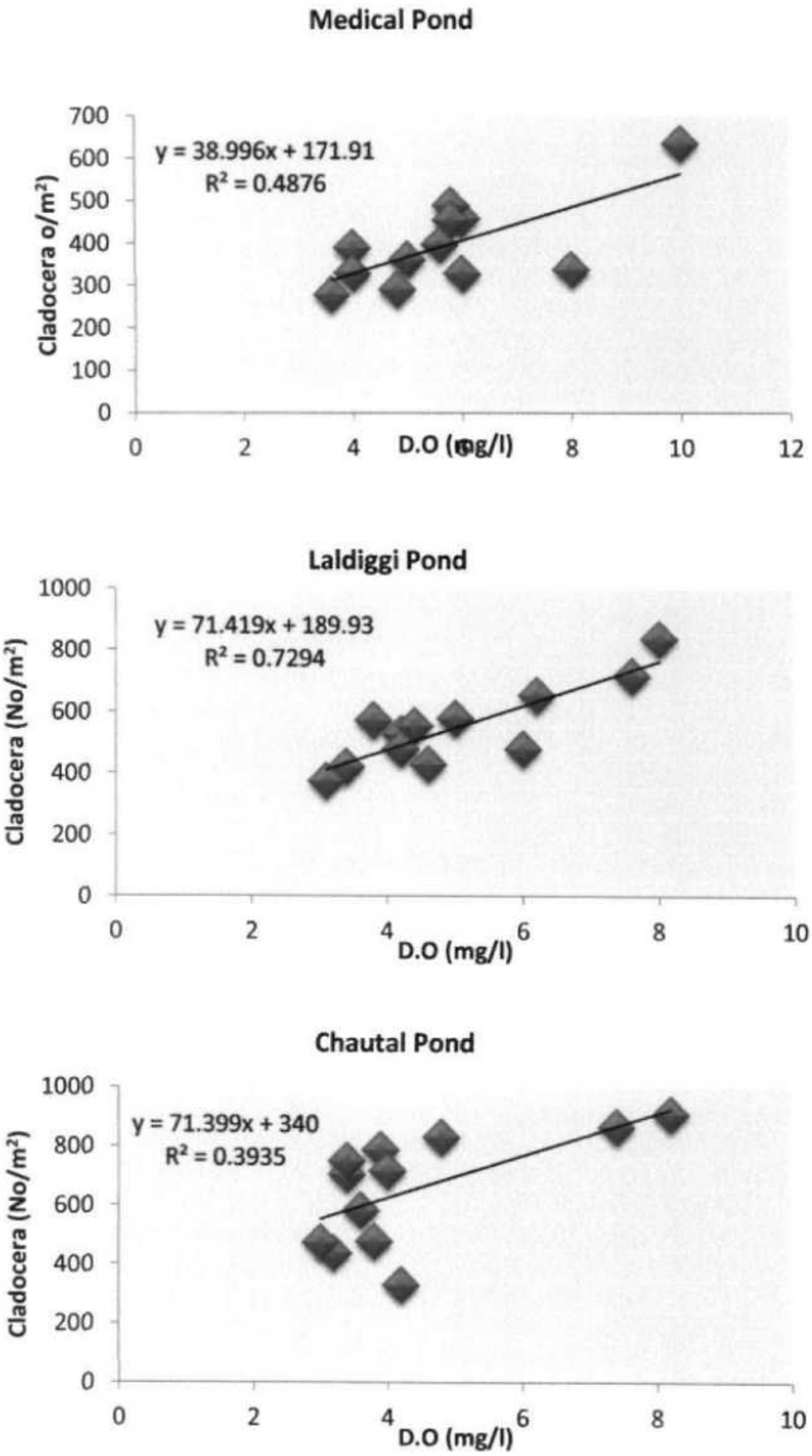
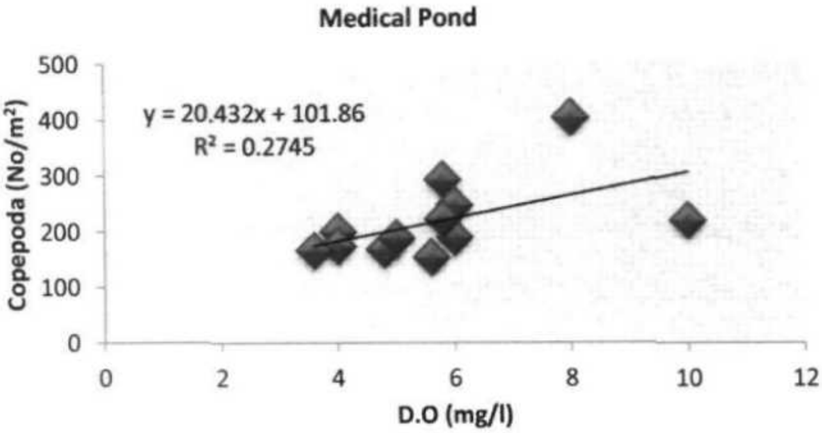
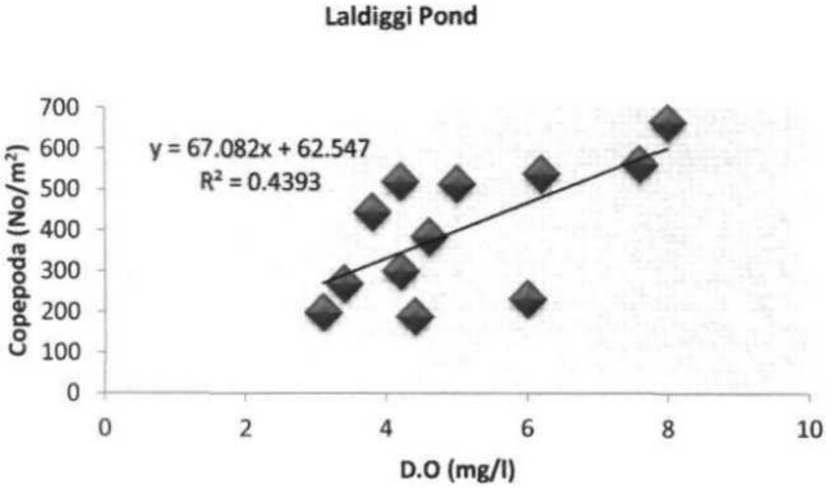


Fig.13- Regression lines showing relationship between Cladocera (No/m²) and Dissolved Oxygen (mg/l) in Medical Pond, Laldiggi Pond and Chautal Pond





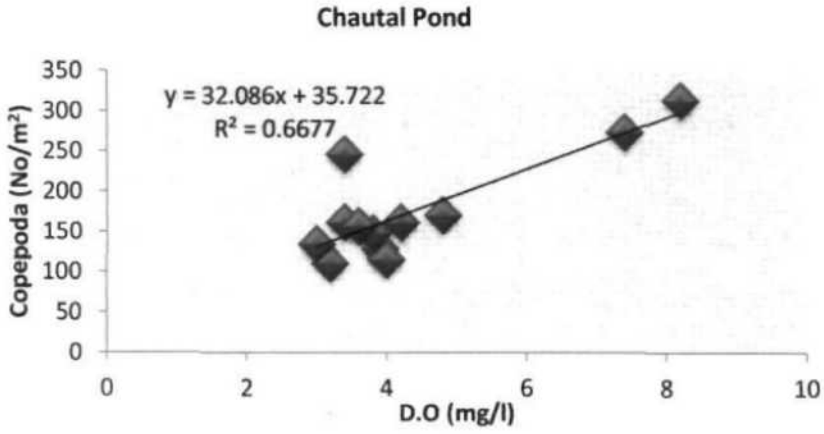
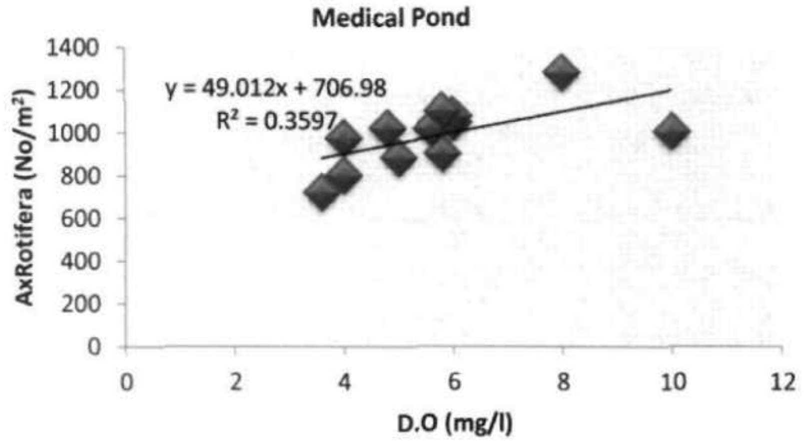
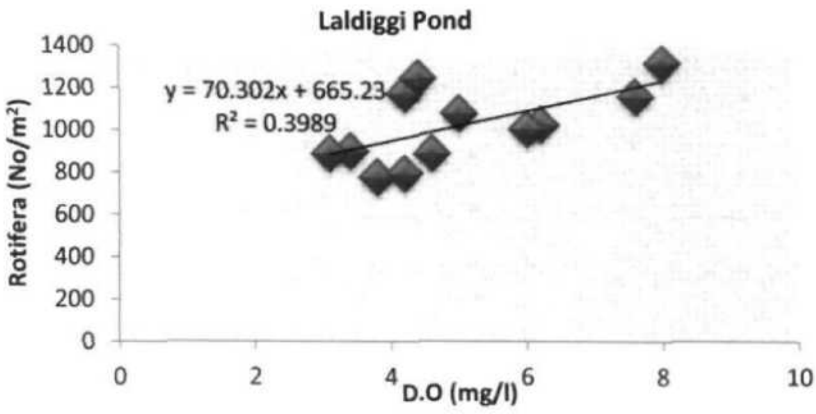


Fig.14- Regression lines showing relationship between Copepoda (No/m^2) and Dissolved Oxygen (mg/l) in Medical Pond, Laldiggi Pond and Chautal Pond





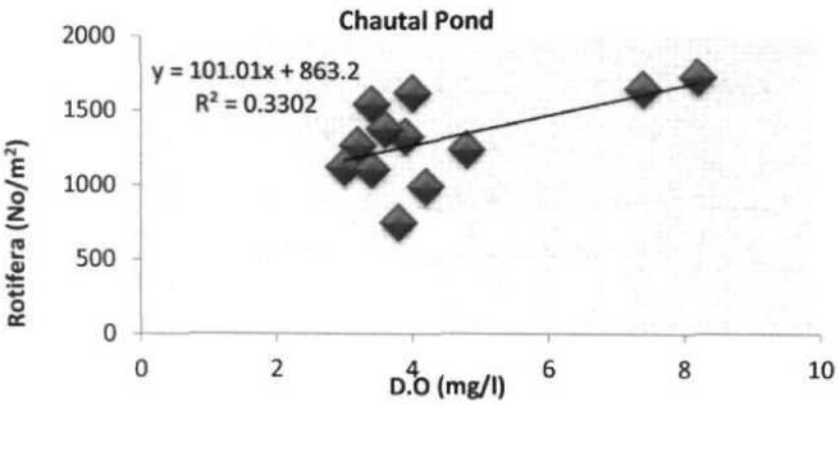
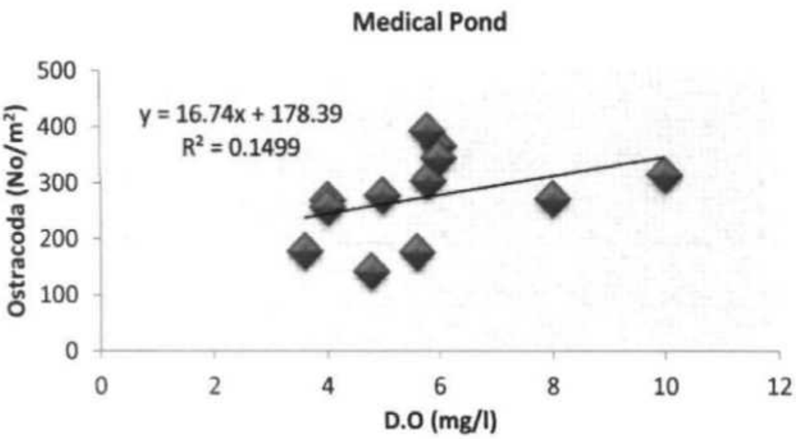
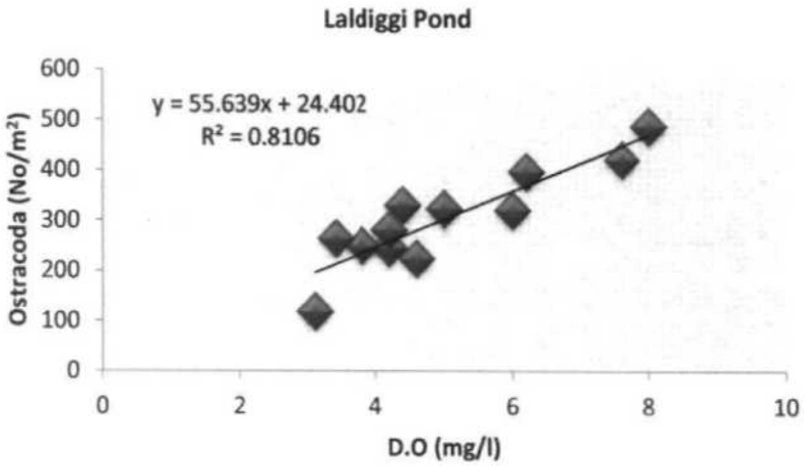


Fig.15- Regression lines showing relationship between Rotifera (No/m²) and Dissolved Oxygen (mg/l) in Medical Pond, Laldiggi Pond and Chautal Pond





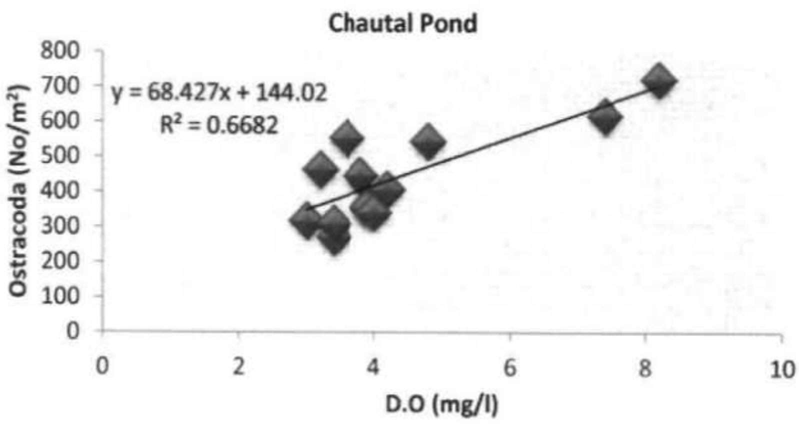


Fig.16- Regression lines showing relationship between Ostracoda (No/m^2) and Dissolved Oxygen (mg/l) in Medical Pond, Laldiggi Pond and Chautal Pond

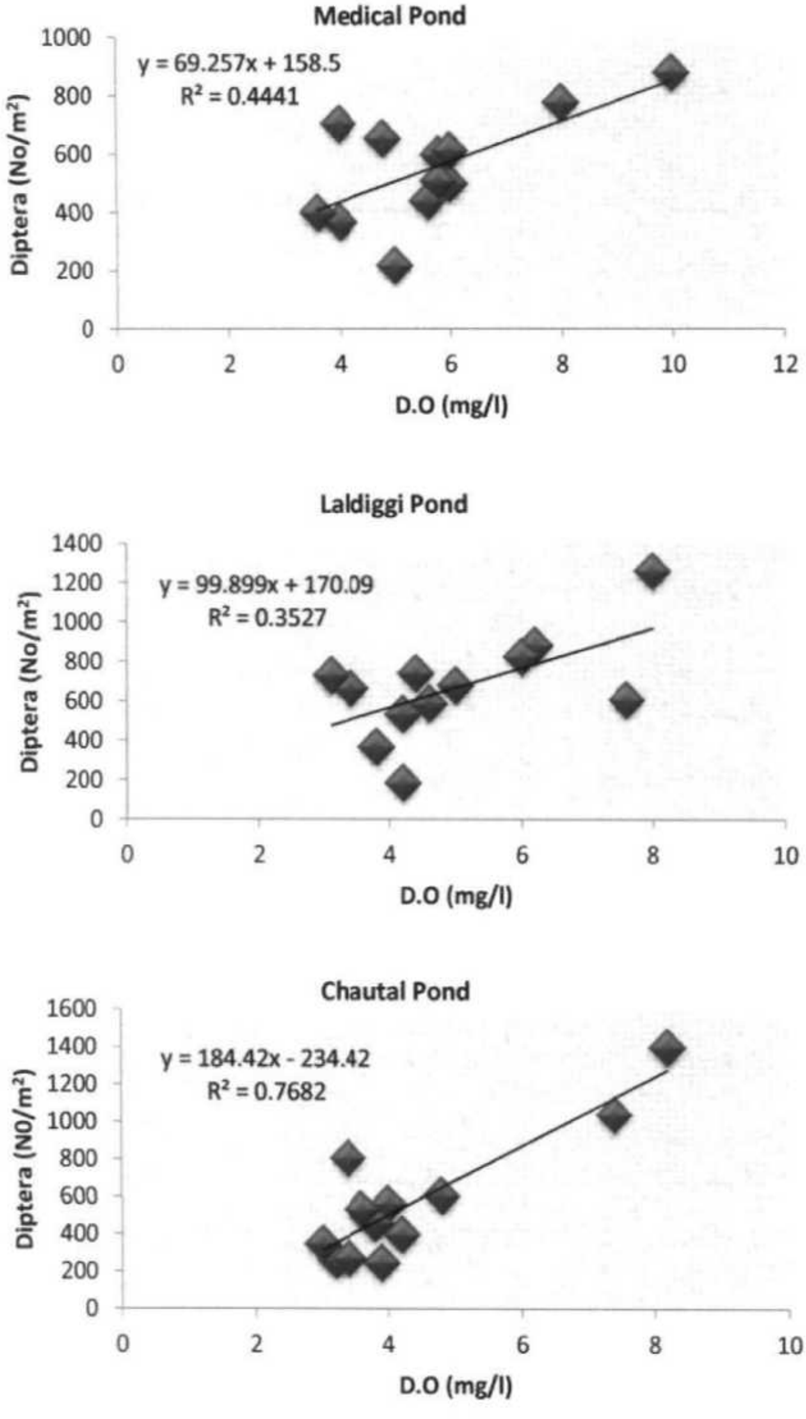
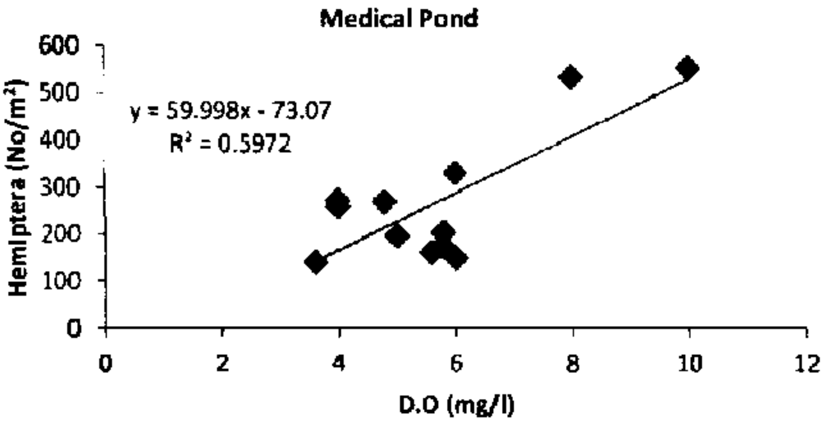
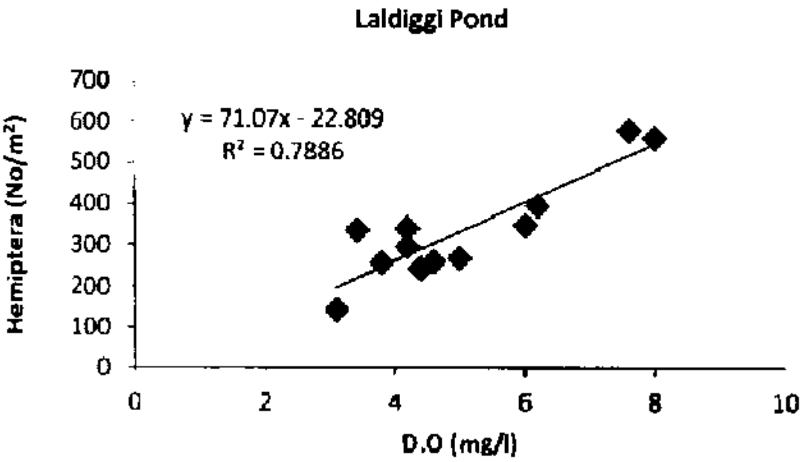


Fig.17- Regression lines showing relationship between Diptera (No/m^2) and Dissolved Oxygen (mg/l) in Medical Pond, Laldiggi Pond and Chautal Pond





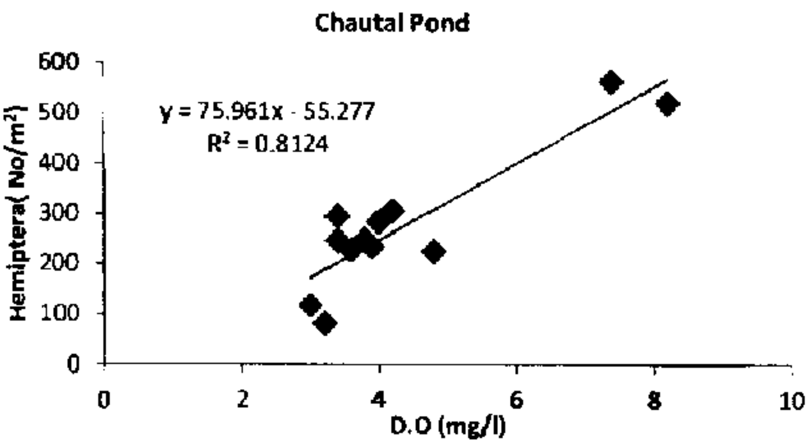
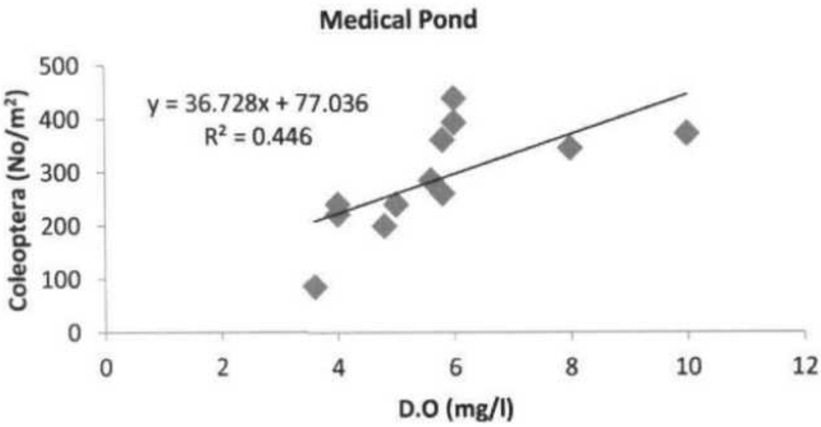
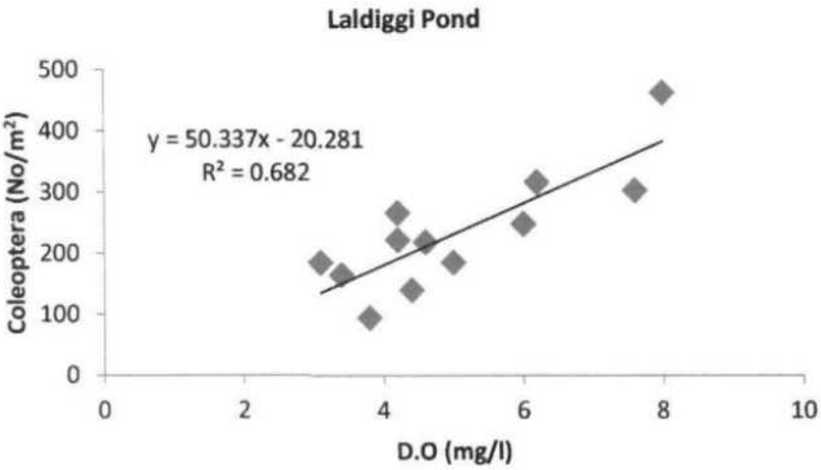


Fig.18- Regression lines showing relationship between Hemiptera (No/m²) and Dissolved Oxygen (mg/l) in Medical Pond, Laldiggi Pond and Chautal Pond





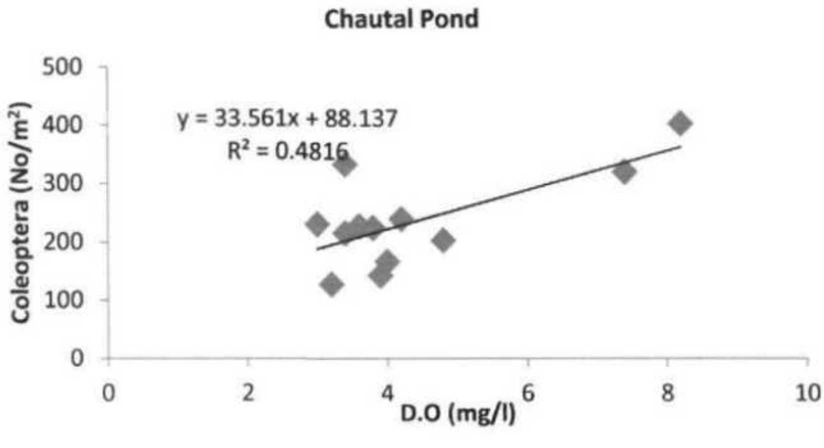
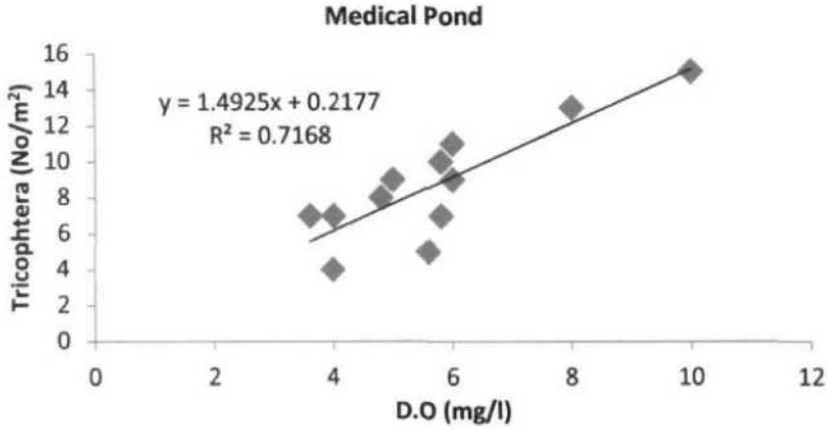
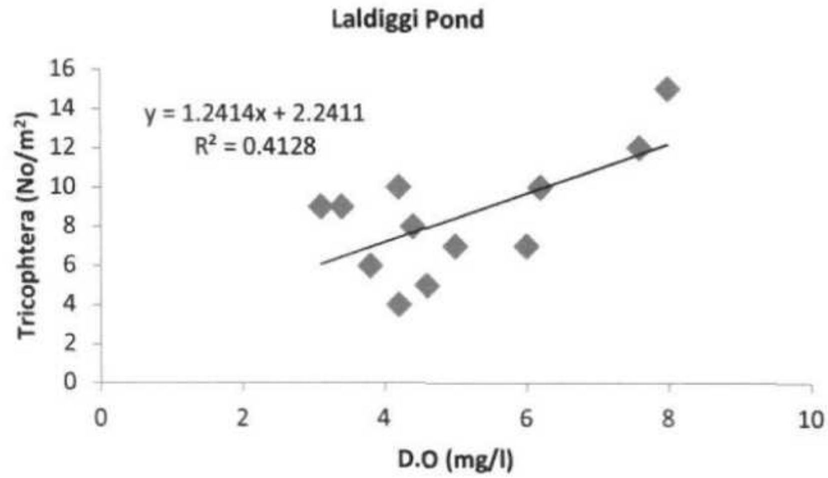


Fig.19- Regression lines showing relationship between Coleoptera (No/m^2) and Dissolved Oxygen (mg/l) in Medical Pond, Laldiggi Pond and Chautal Pond





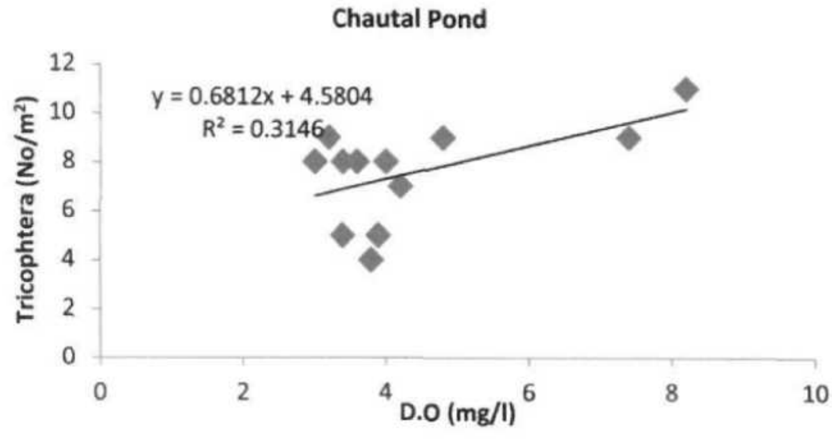
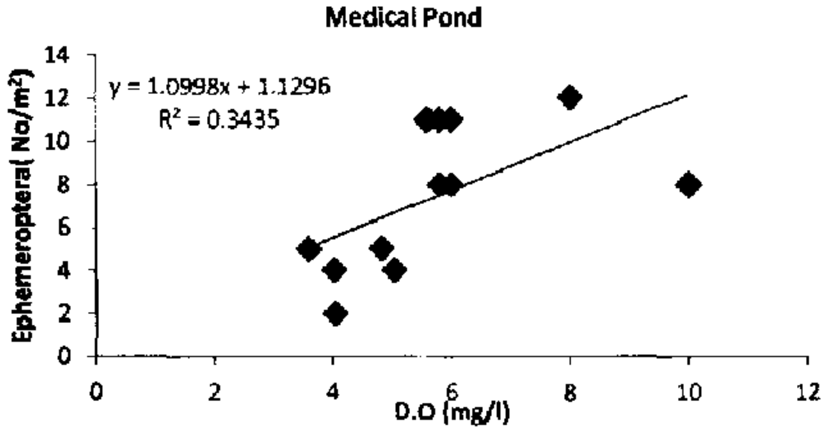
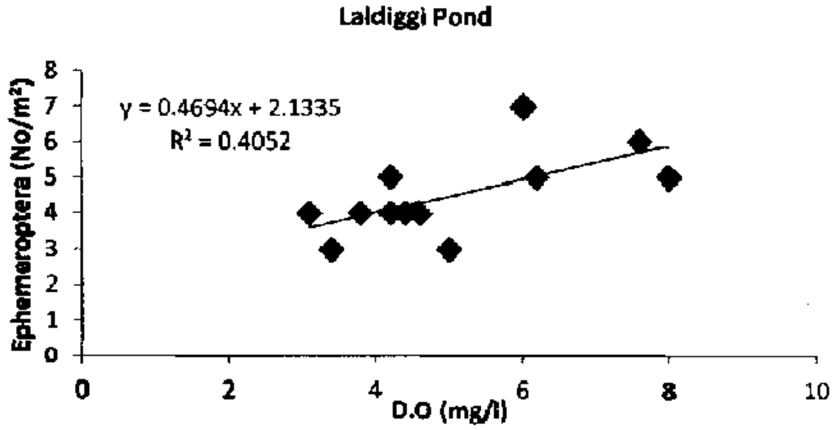


Fig.20- Regression lines showing relationship between Trichoptera (No/m^2) and Dissolved Oxygen (mg/l) in Medical Pond, Laldiggi Pond and Chautal Pond





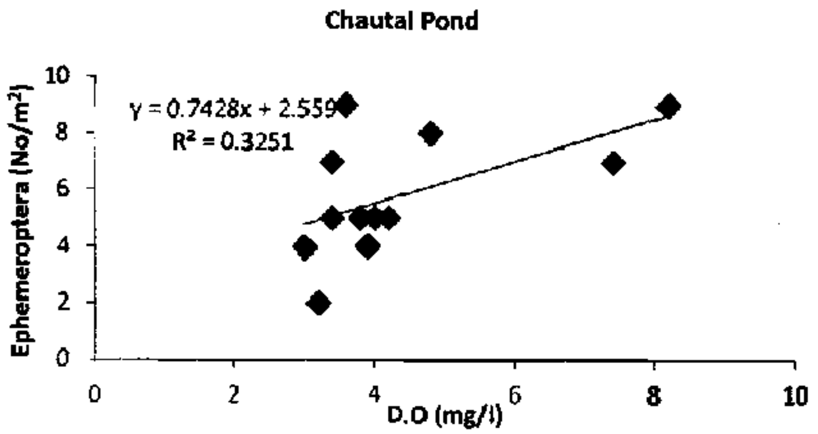
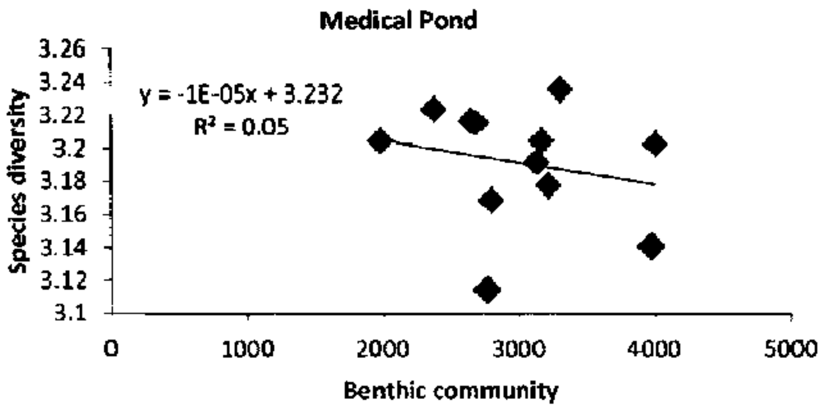
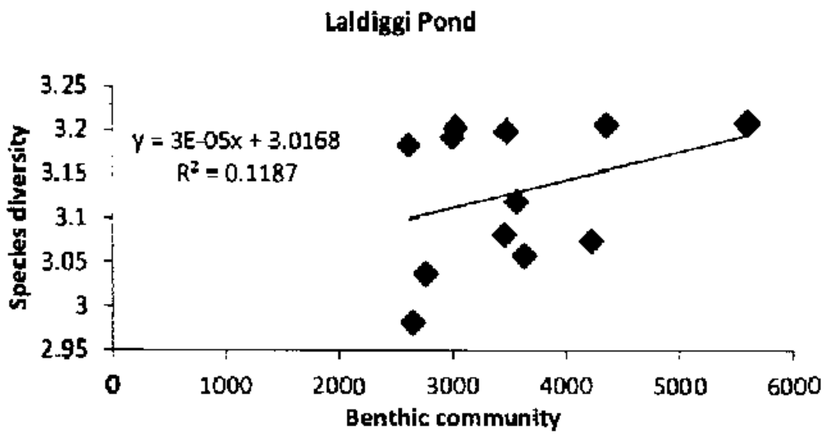


Fig.21- Regression lines showing relationship between Ephemeroptera (No/m²) and Dissolved Oxygen (mg/l) in Medical Pond, Laldiggi Pond and Chautal Pond





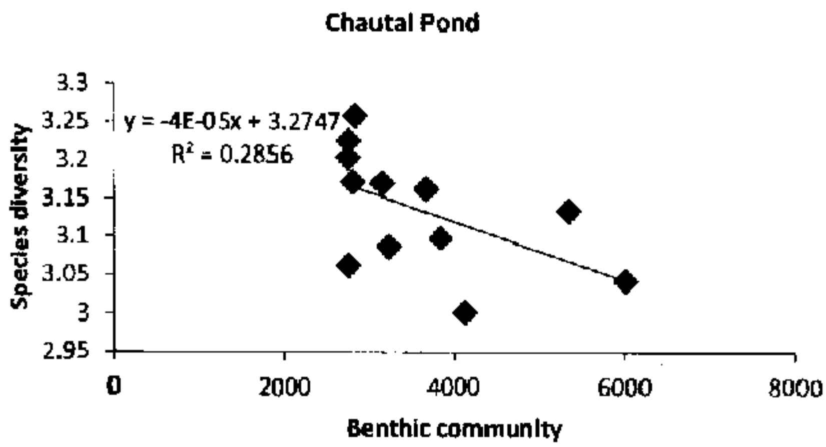


Fig.22- Regression lines showing relationship between Benthos density (No/m^2) and Species diversity in Medical Pond, Laldiggi Pond and Chautal Pond

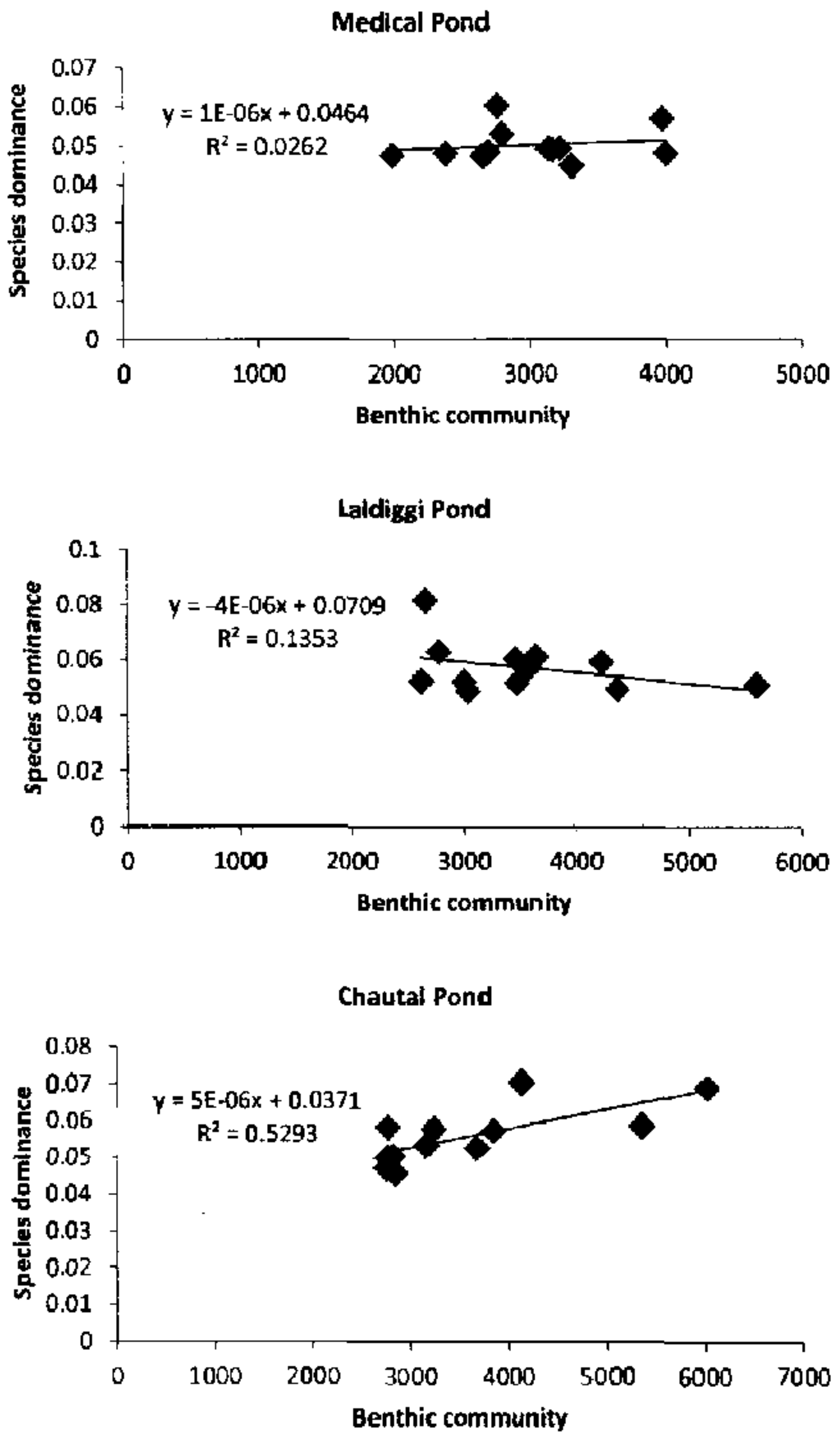
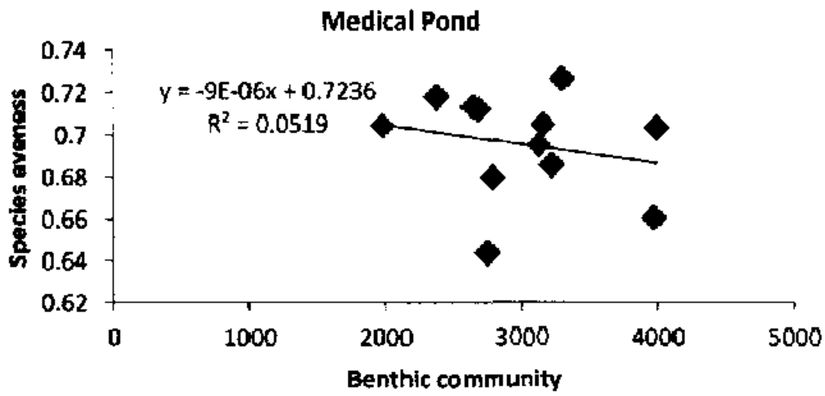
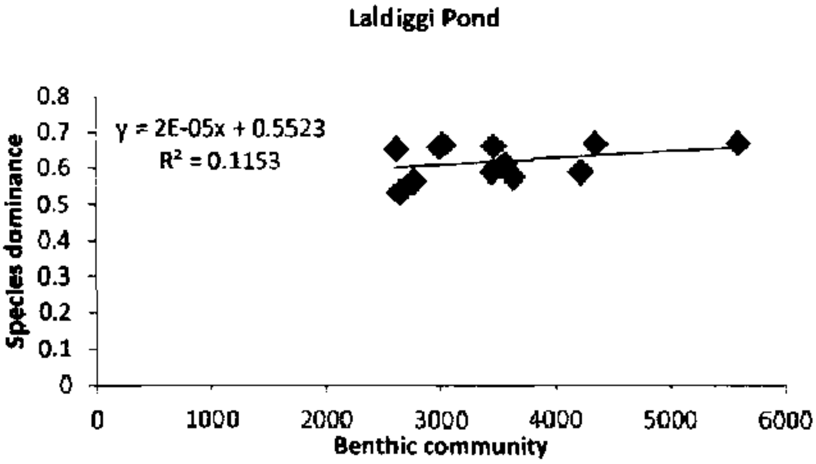


Fig.23- Regression lines showing relationship between Benthos density (No/m^2) and Species dominance in Medical Pond, Laldiggi Pond and Chautal Pond





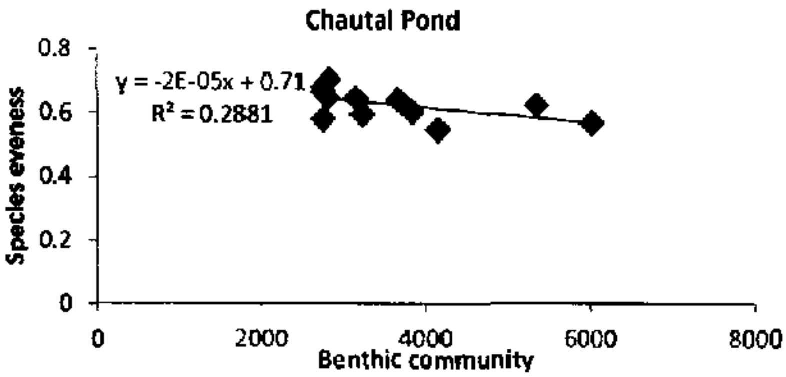


Fig.24- Regression lines showing relationship between Benthic community (No/m^2) and Species eveness in Medical Pond, Laldiggi Pond and Chautal Pond

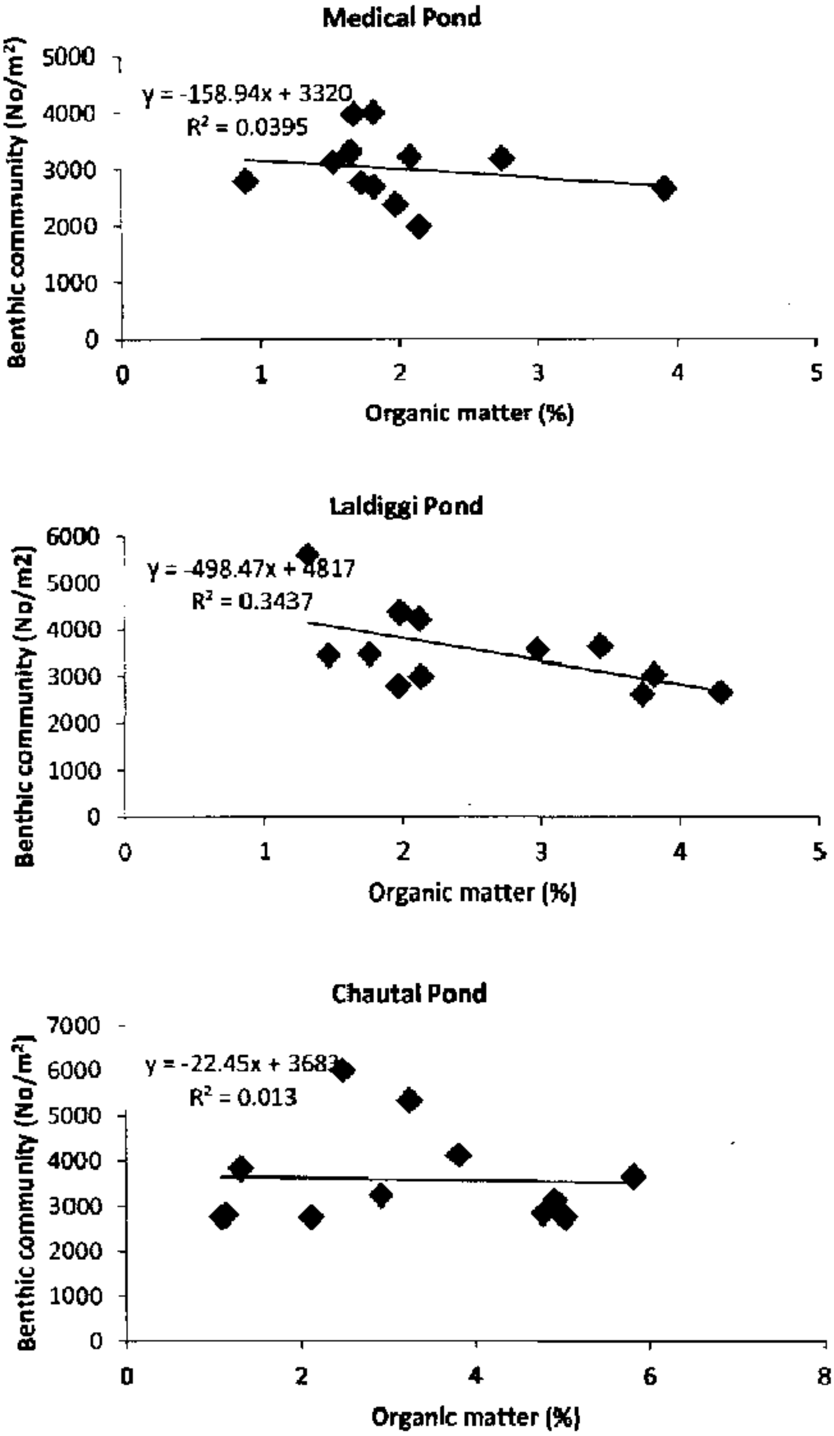
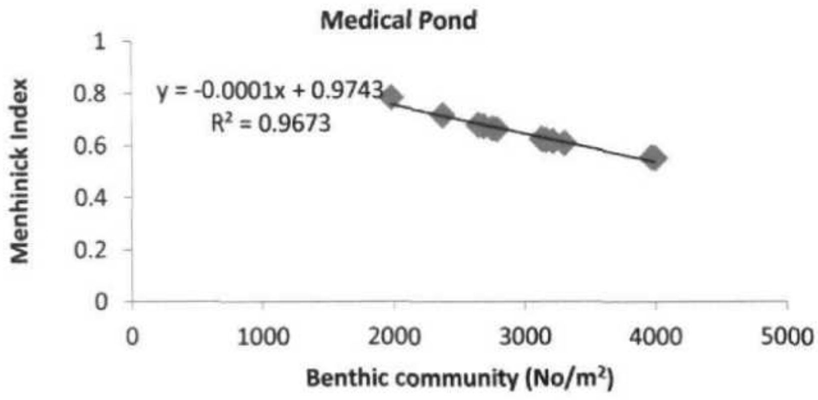
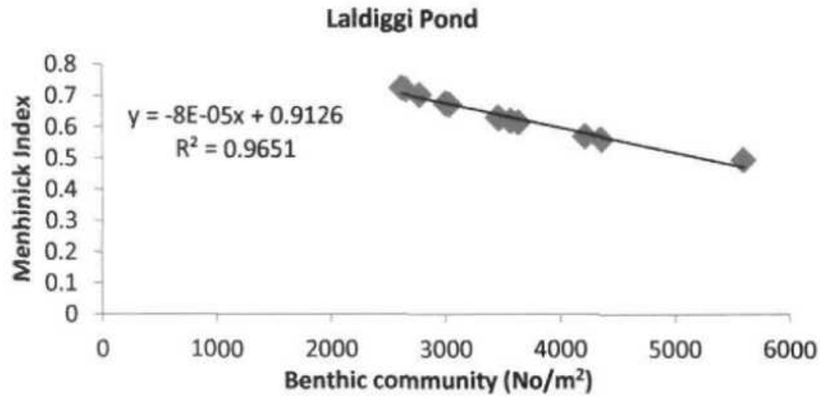


Fig.25- Regression lines showing relationship between Benthos density (No/m^2) and Organic matter (%) in Medical Pond, Laldiggi Pond and Chautal Pond





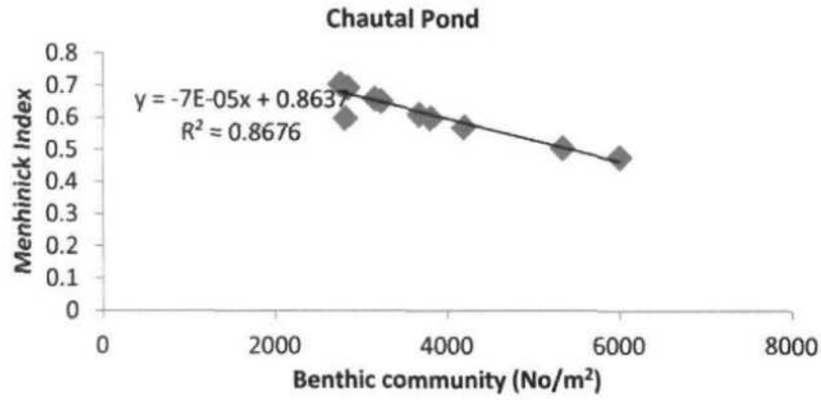


Fig.26- Regression lines showing relationship between Benthos density (No/m^2) and Menhinick Index in Medical Pond, Laldiggi Pond and Chautal Pond

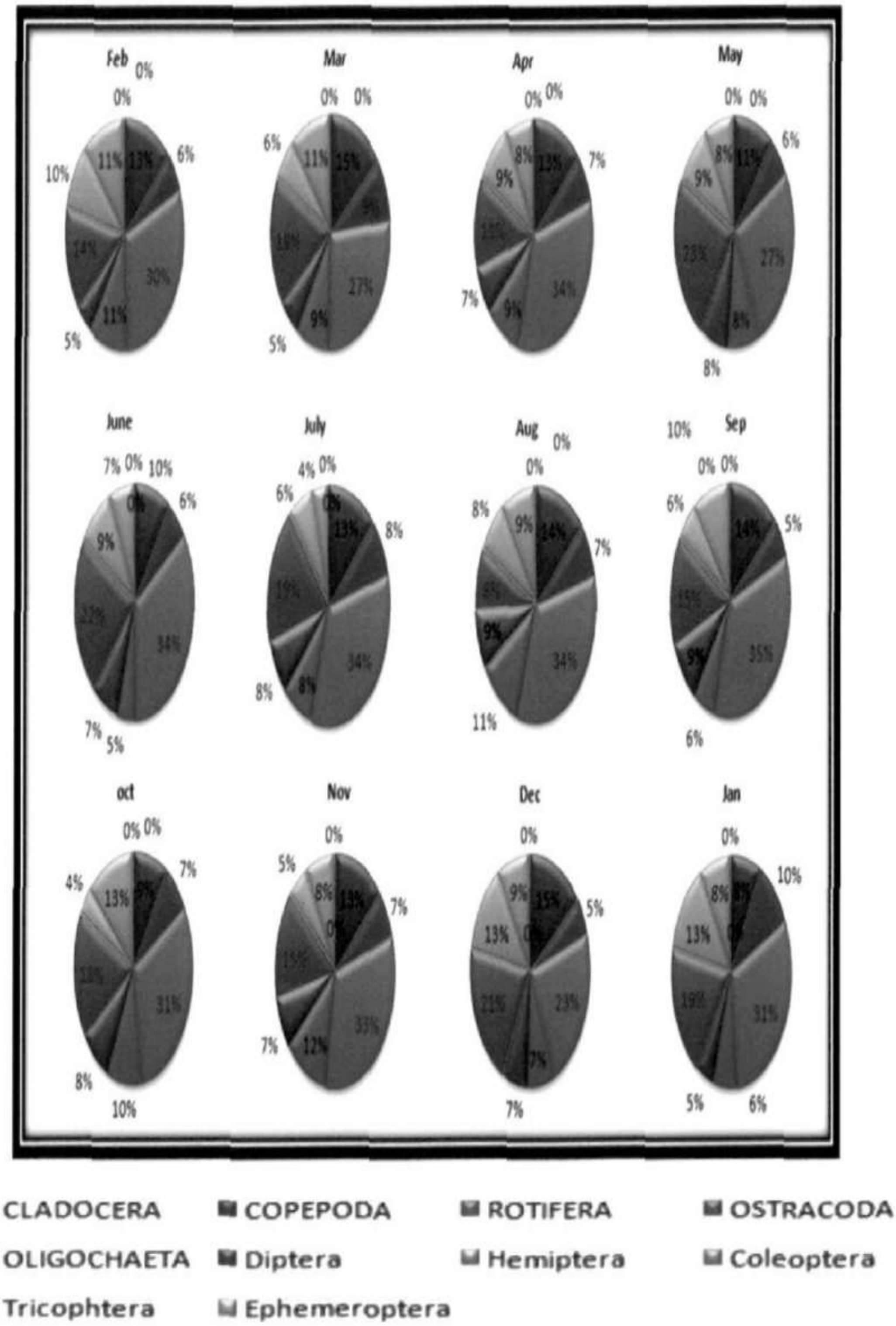


Fig. 27 a Monthly percent composition of different Benthic groups (No/m²) in Medical Pond

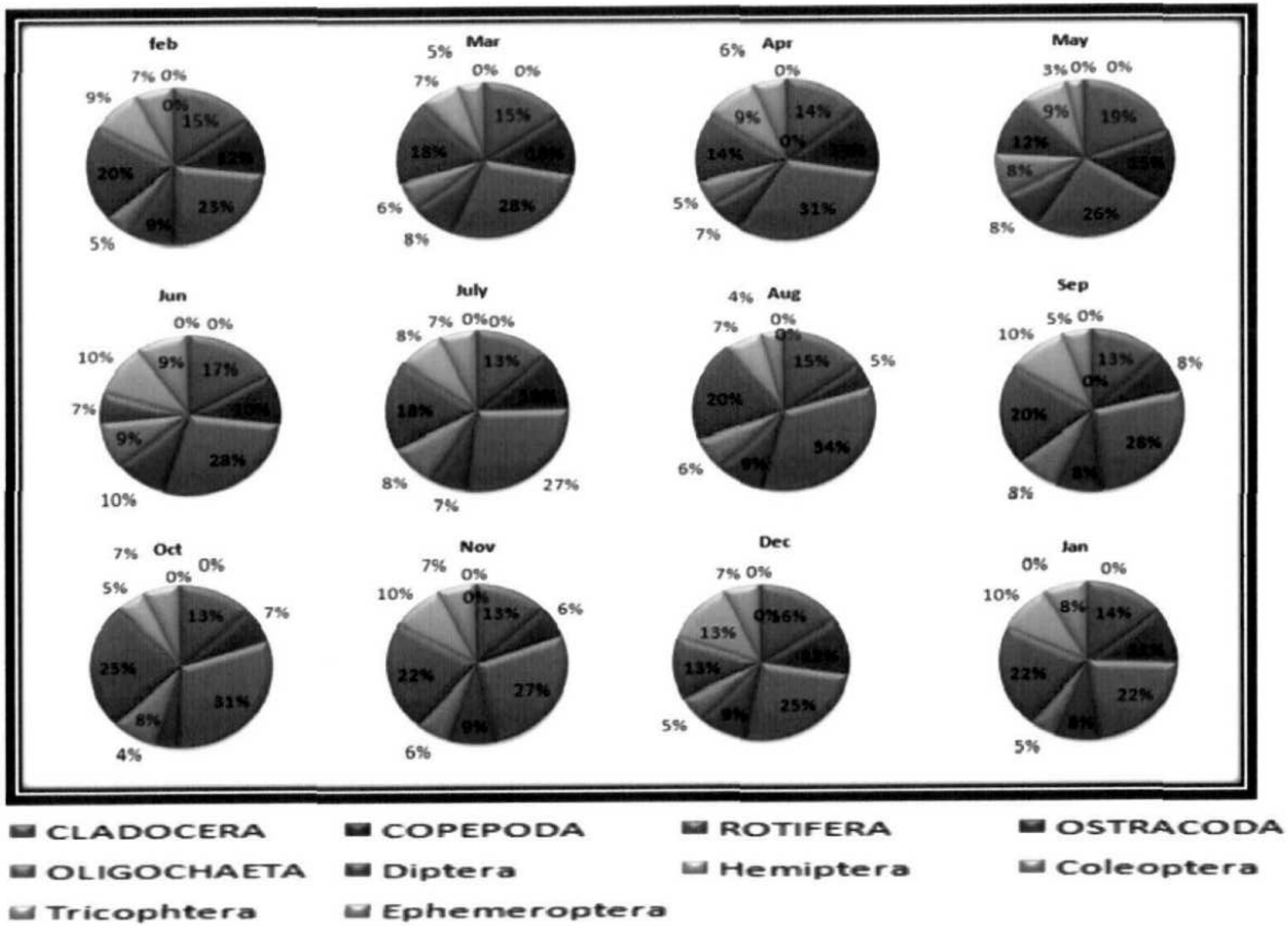


Fig. 27 b Monthly percent composition of different Benthic groups (No/m²) in Laldiggi Pond

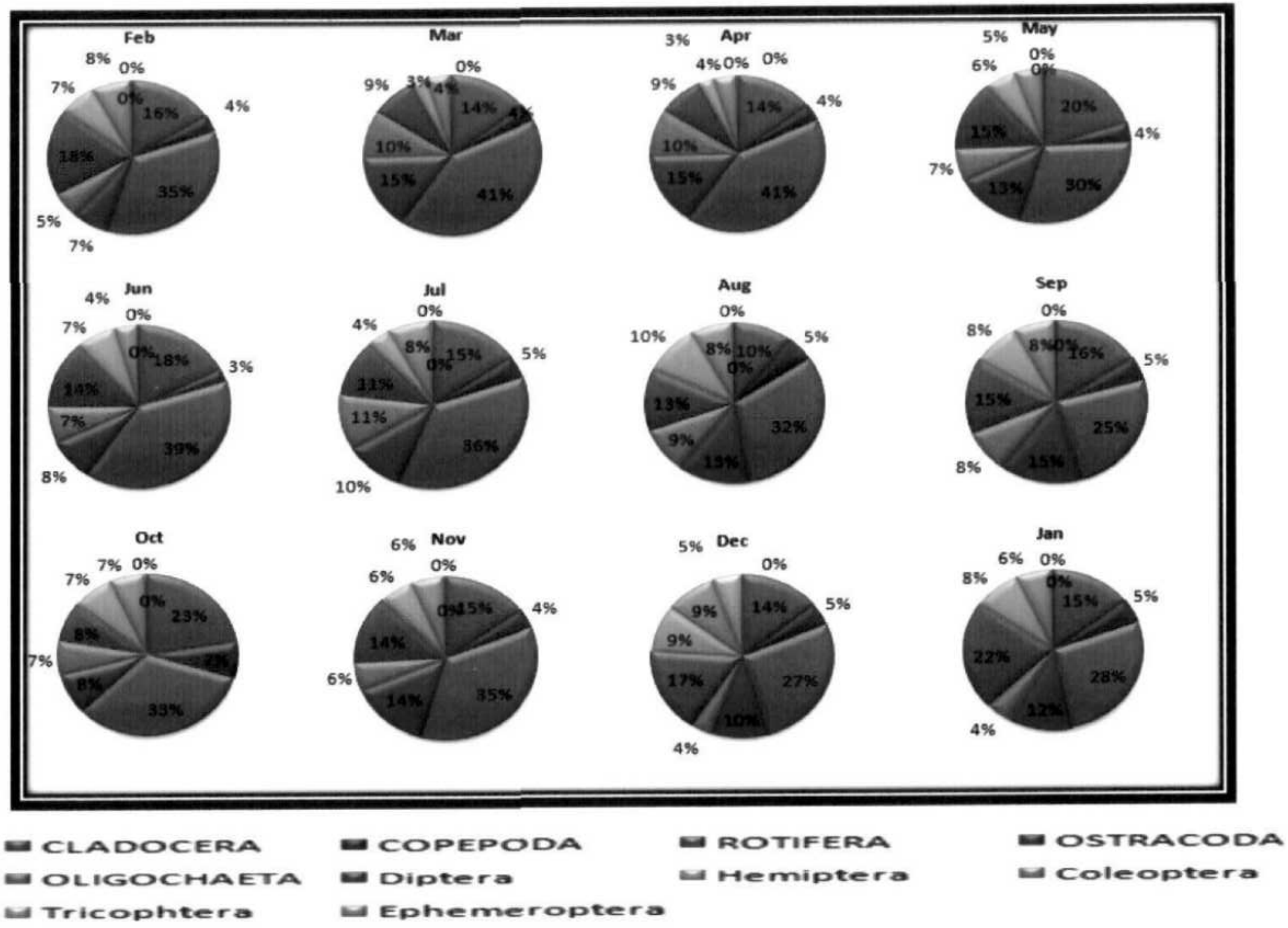


Fig. 27 c Monthly percent composition of different Benthic groups (No/m²) in Chautal Pond

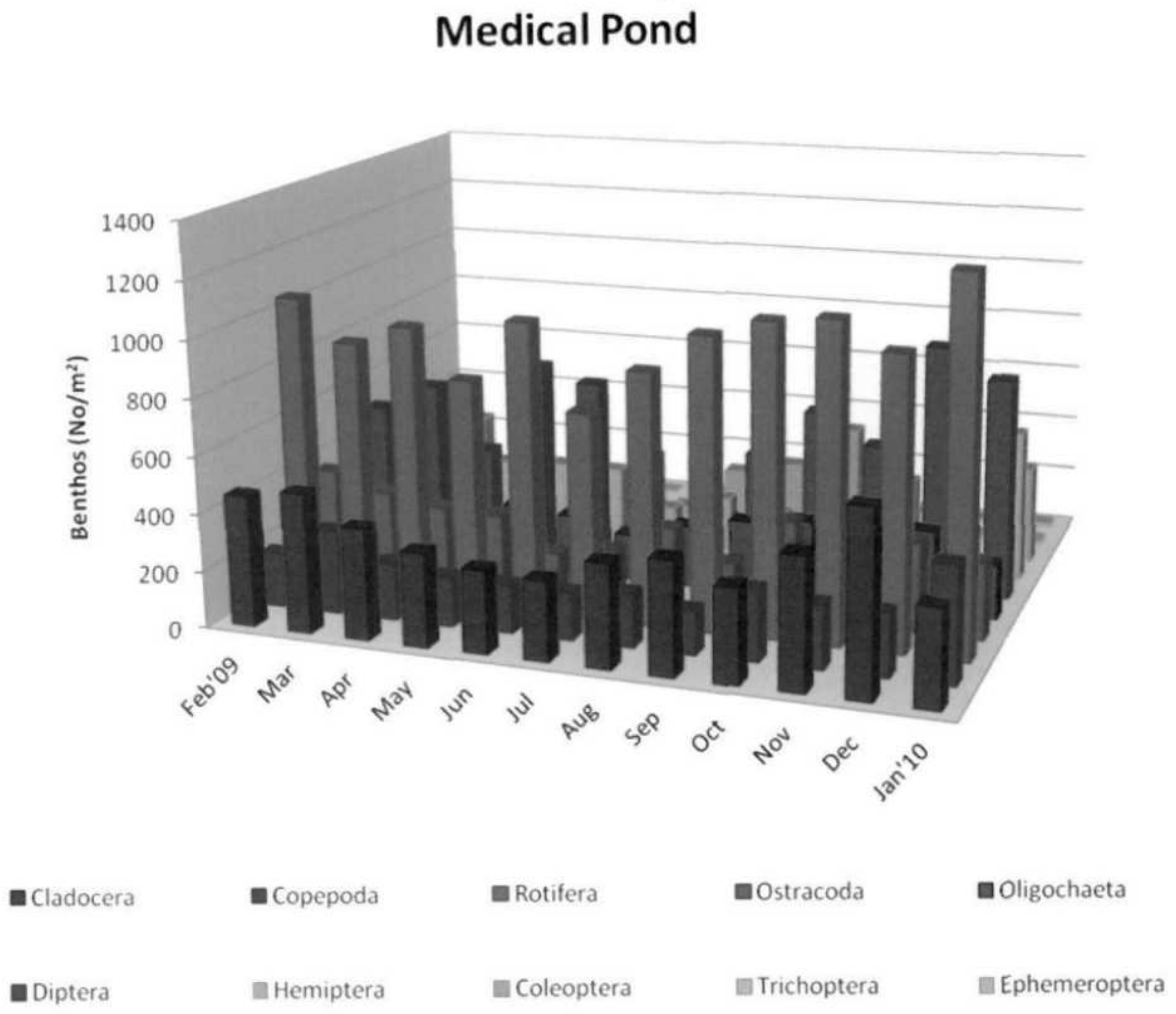


Fig – 28a Histogram showing monthly variations in Benthos (No/m²) in Medical Pond

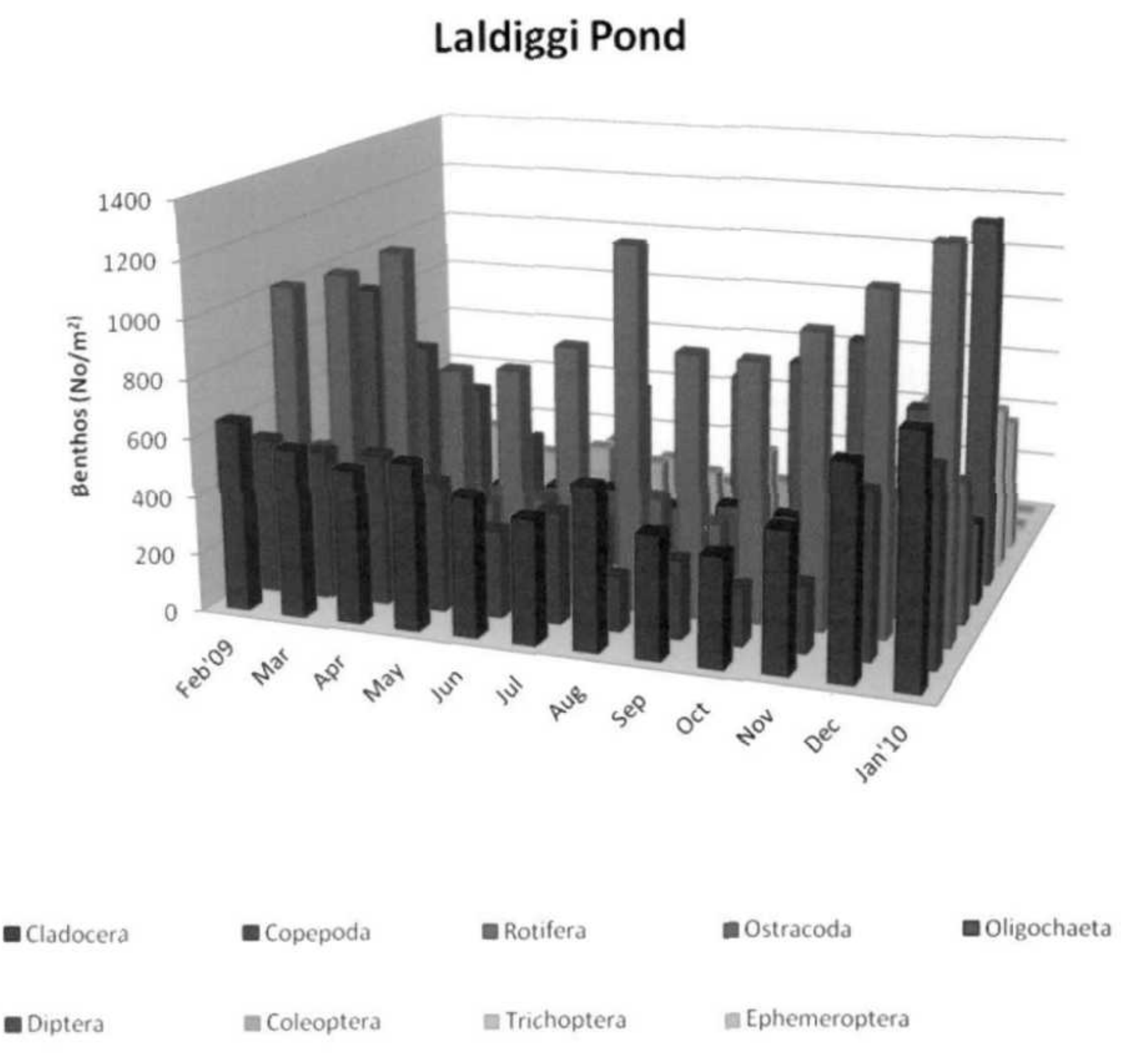


Fig.28b Histogram showing monthly variations in Benthos (No/m^2) in Laldiggi Pond

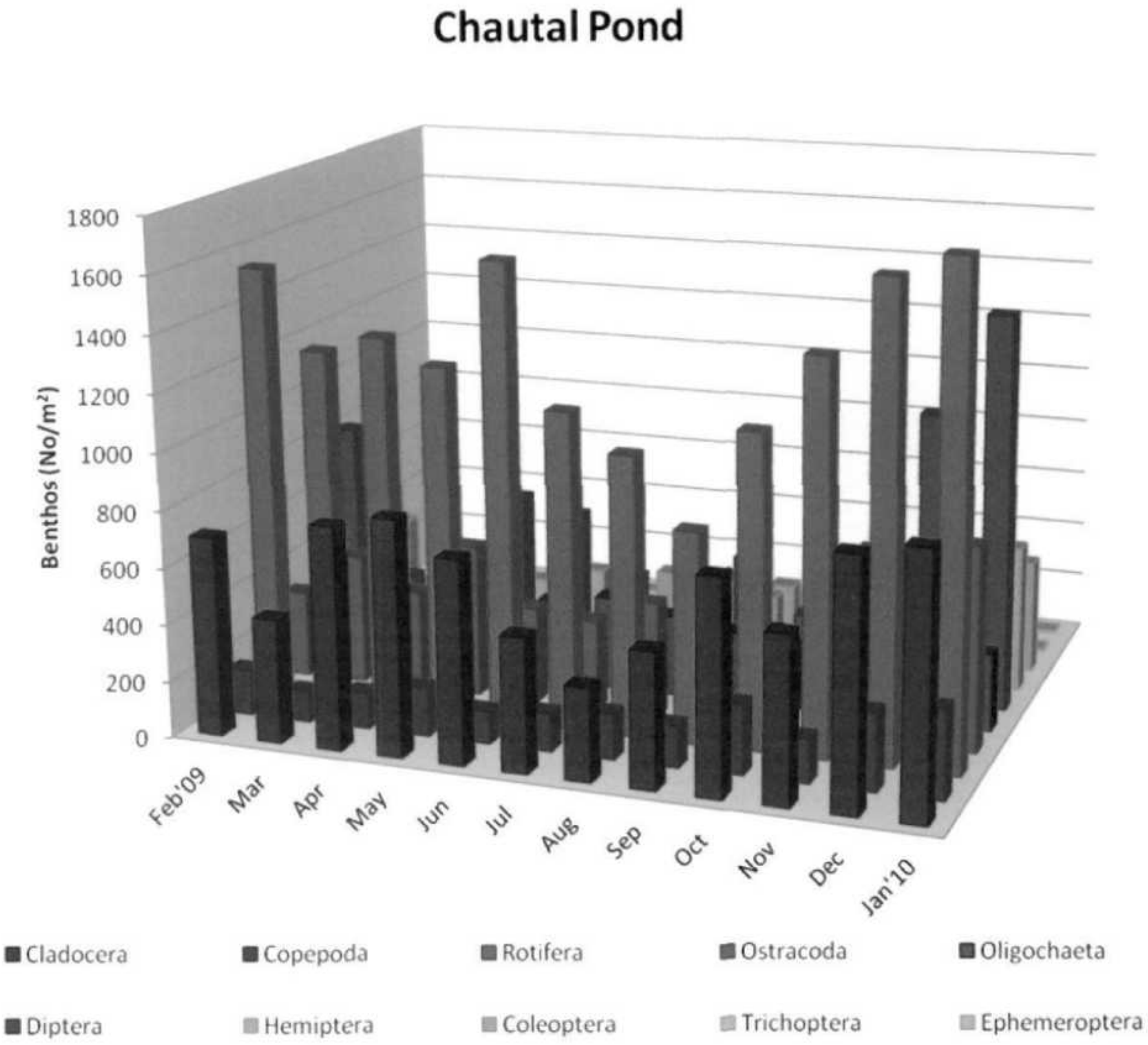
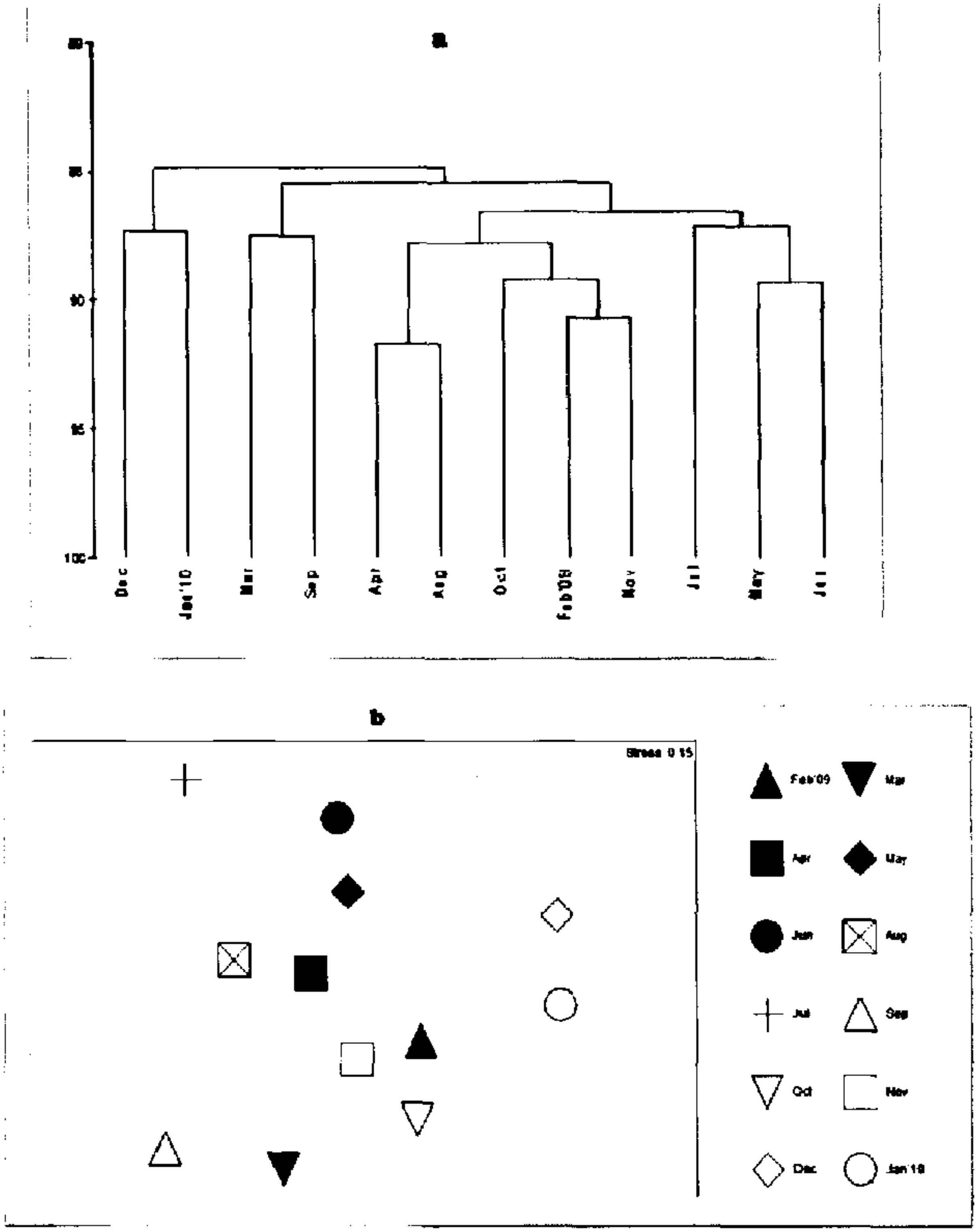


Fig.28c Histogram showing monthly variations in Benthos (No/m²) in Chautal Pond

a



b

Fig. 29: Dendogram and MDS showing similarity of Benthic community between different months in Medical Pond

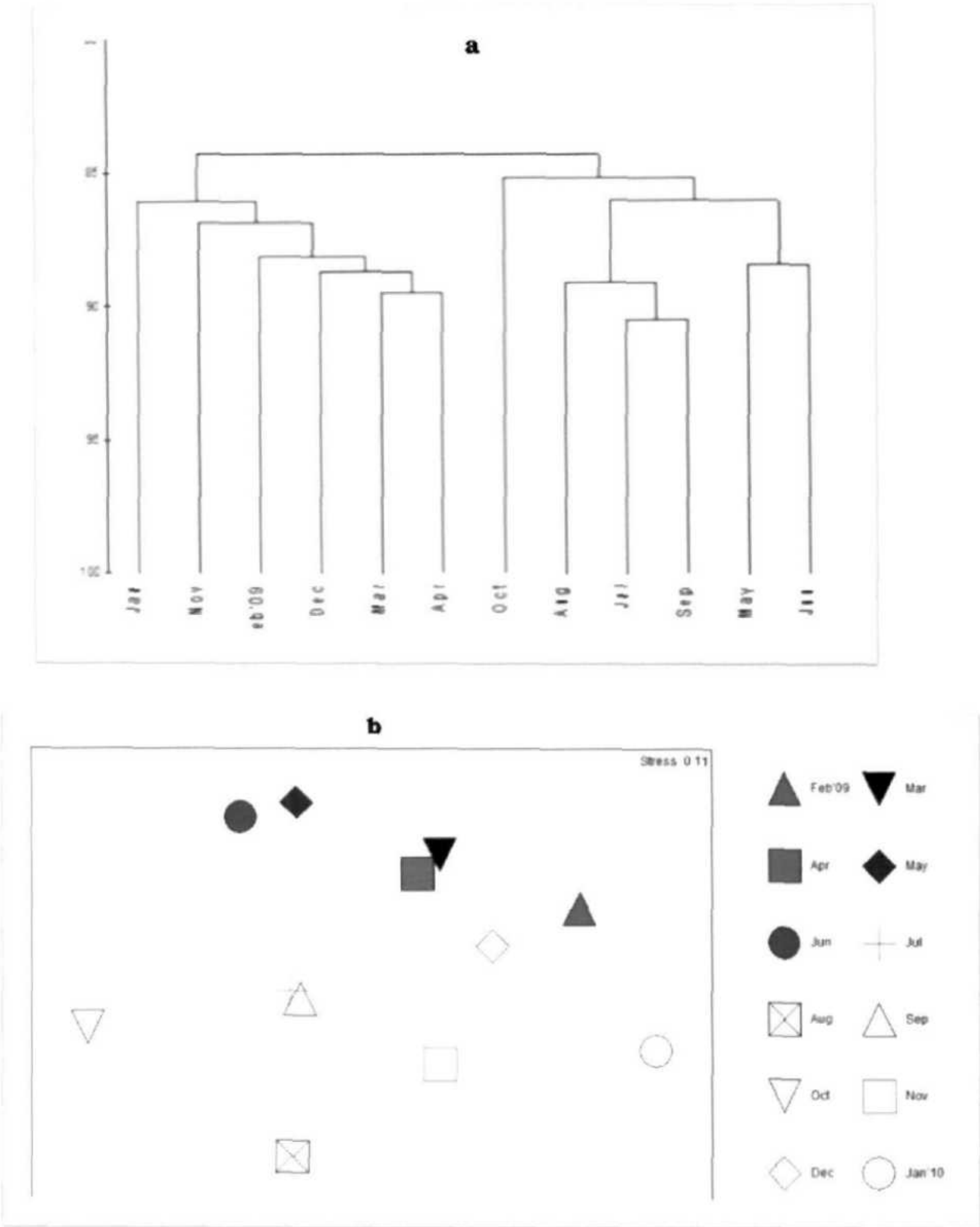


Fig. 30: Dendogram and MDS showing similarity of Benthic community between different months in Laldiggi Pond

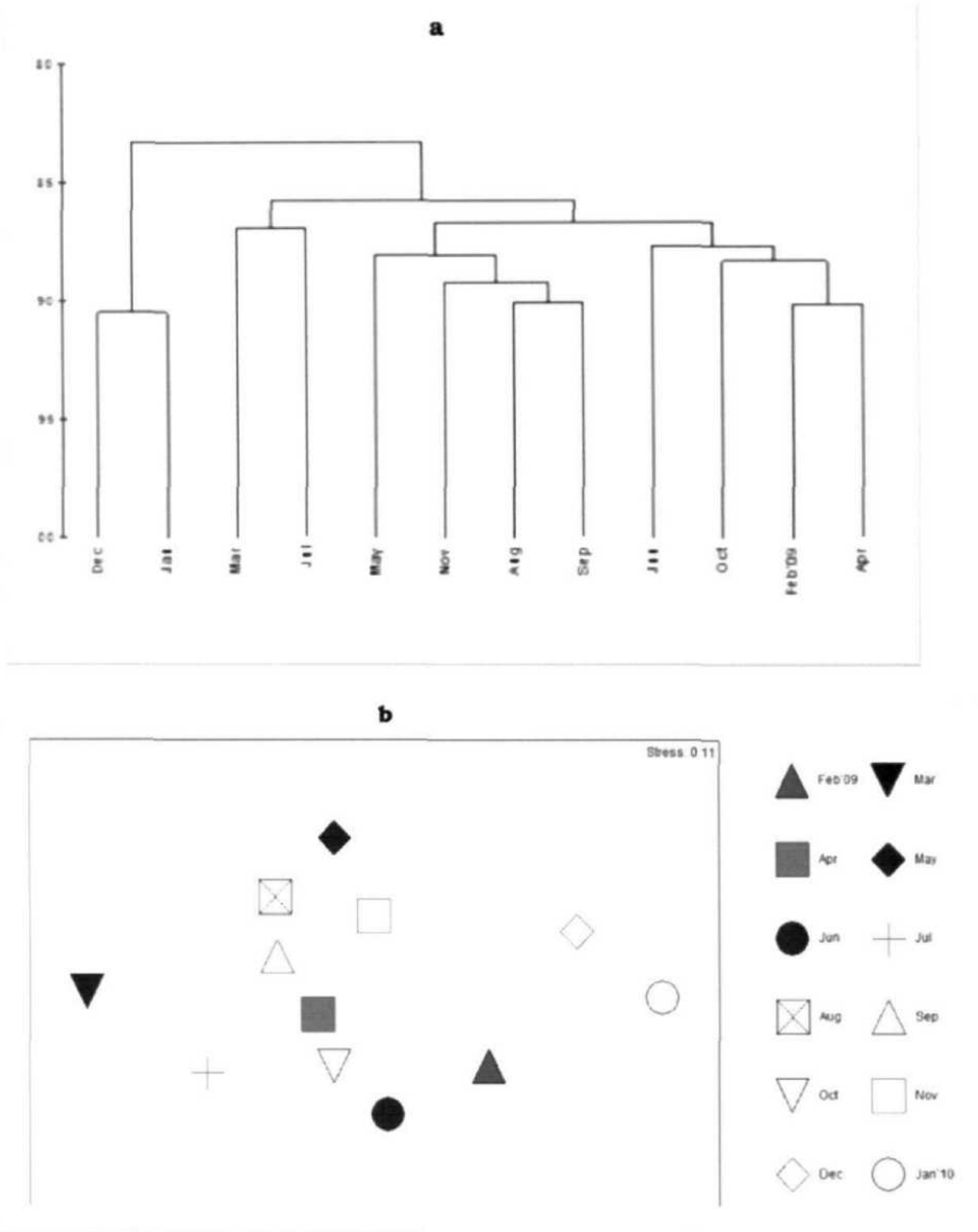


Fig. 31: Dendogram and MDS showing similarity of Benthic community between different months in Chautal Pond

(a) Dendogram (b) MDS

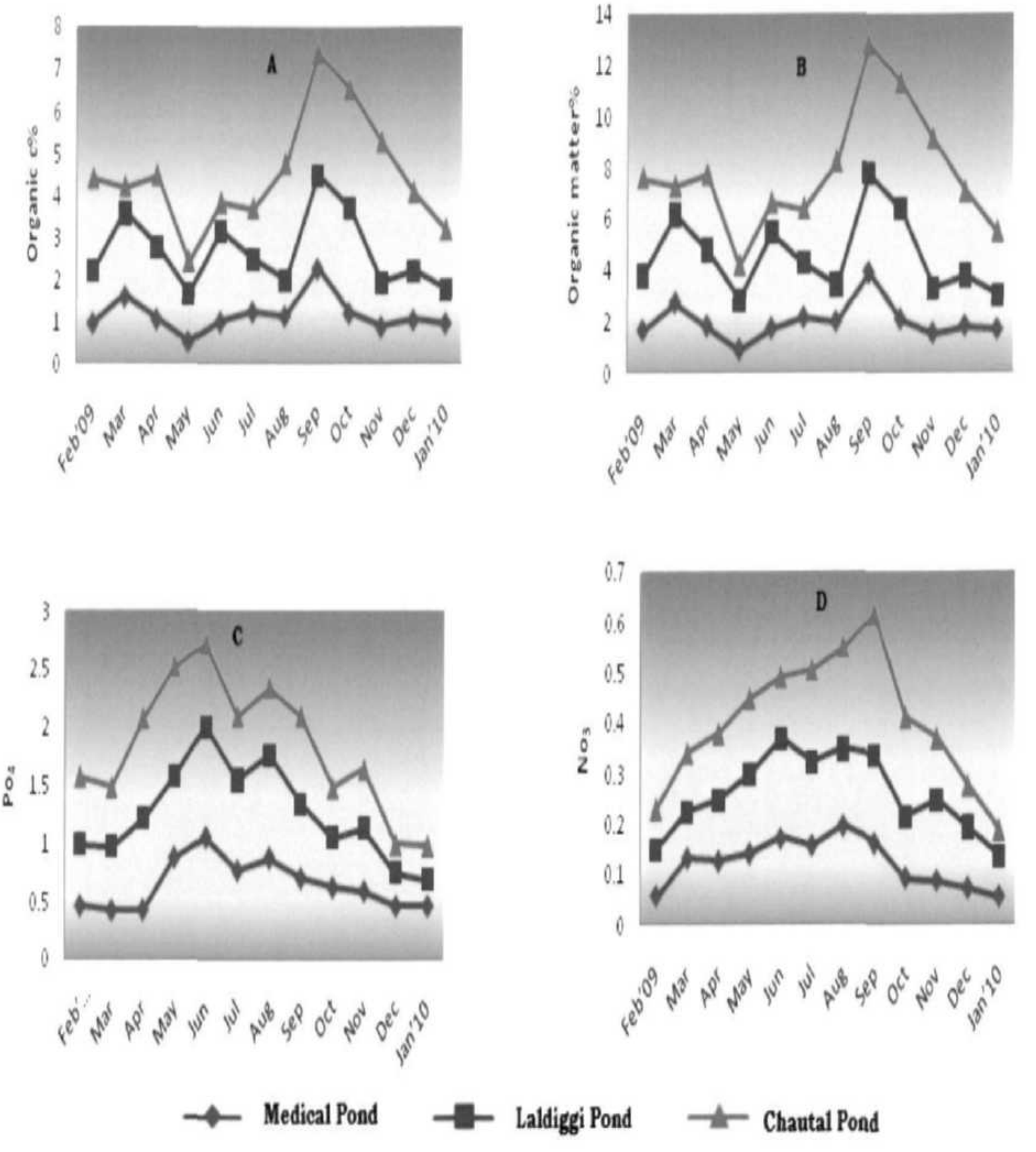


Fig.32: Line diagram showing variations in (A) % organic C,(B) % organic matter, (C) PO_4-P and (D) NO_3-N during study period in Medical Pond, Laldiggi Pond and Chautal Pond

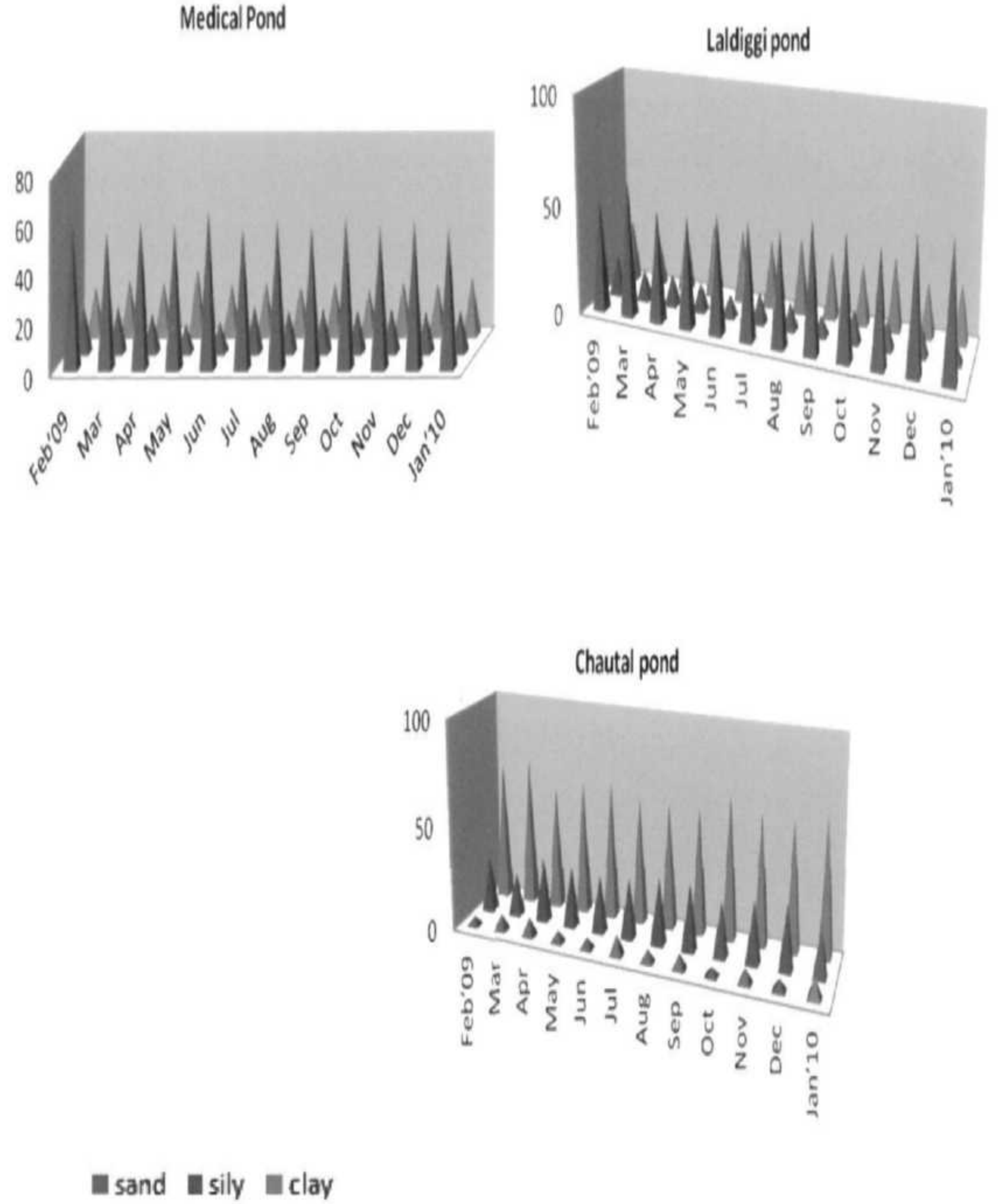


Fig.33: Line diagram showing variations in composition of sand silt and clay (%) during study period in Medical Pond, Laldiggi Pond and Chautal Pond

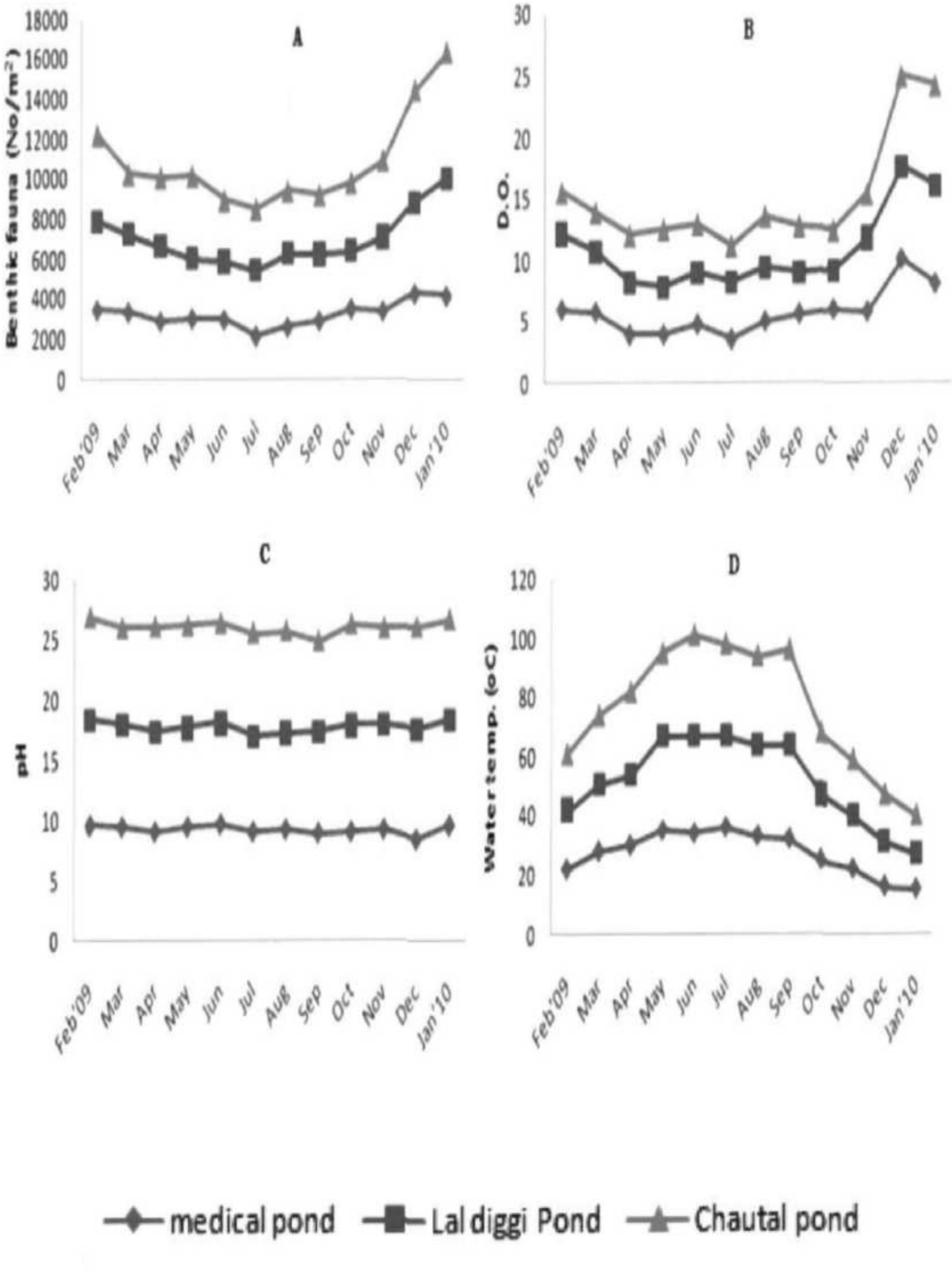
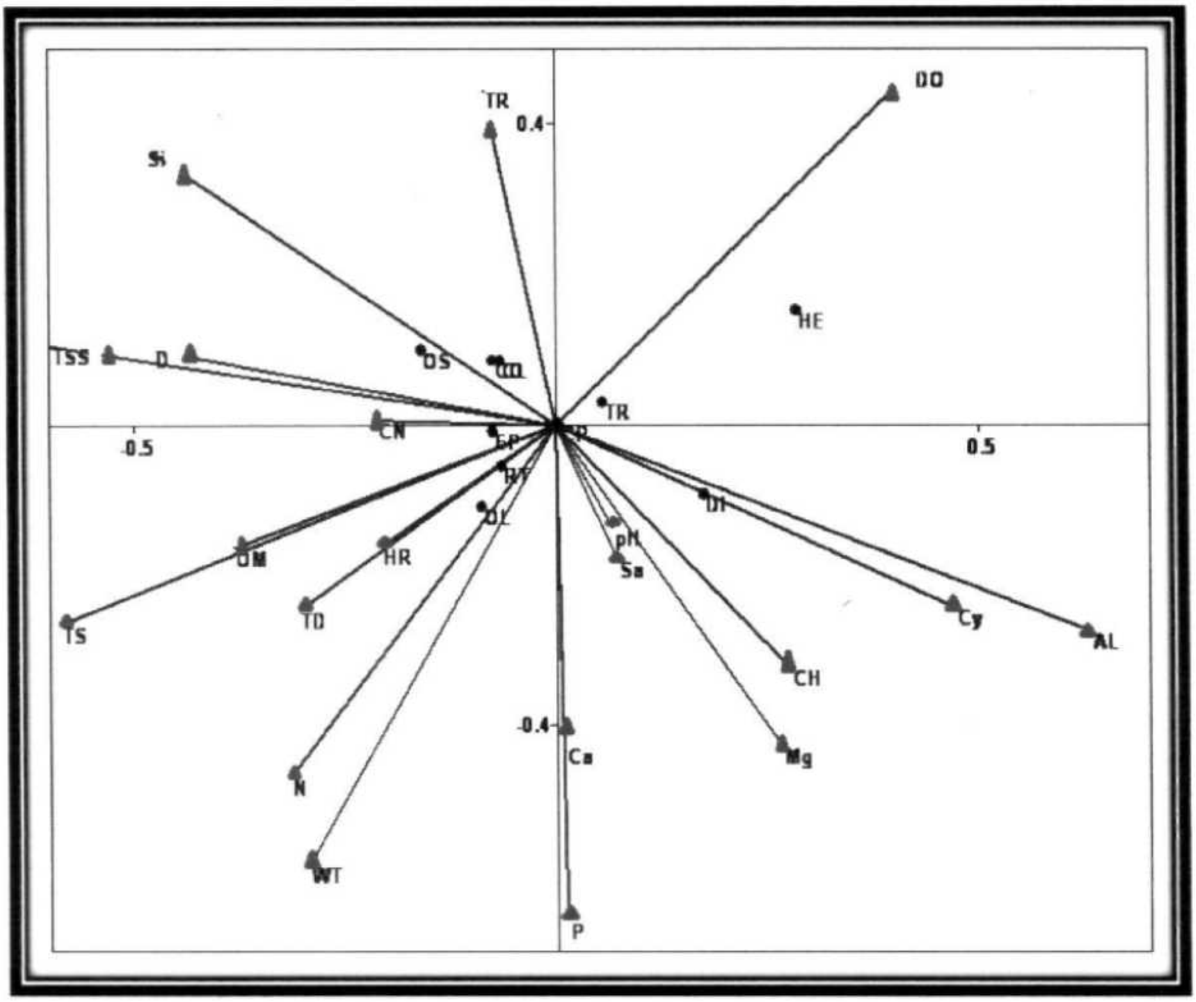
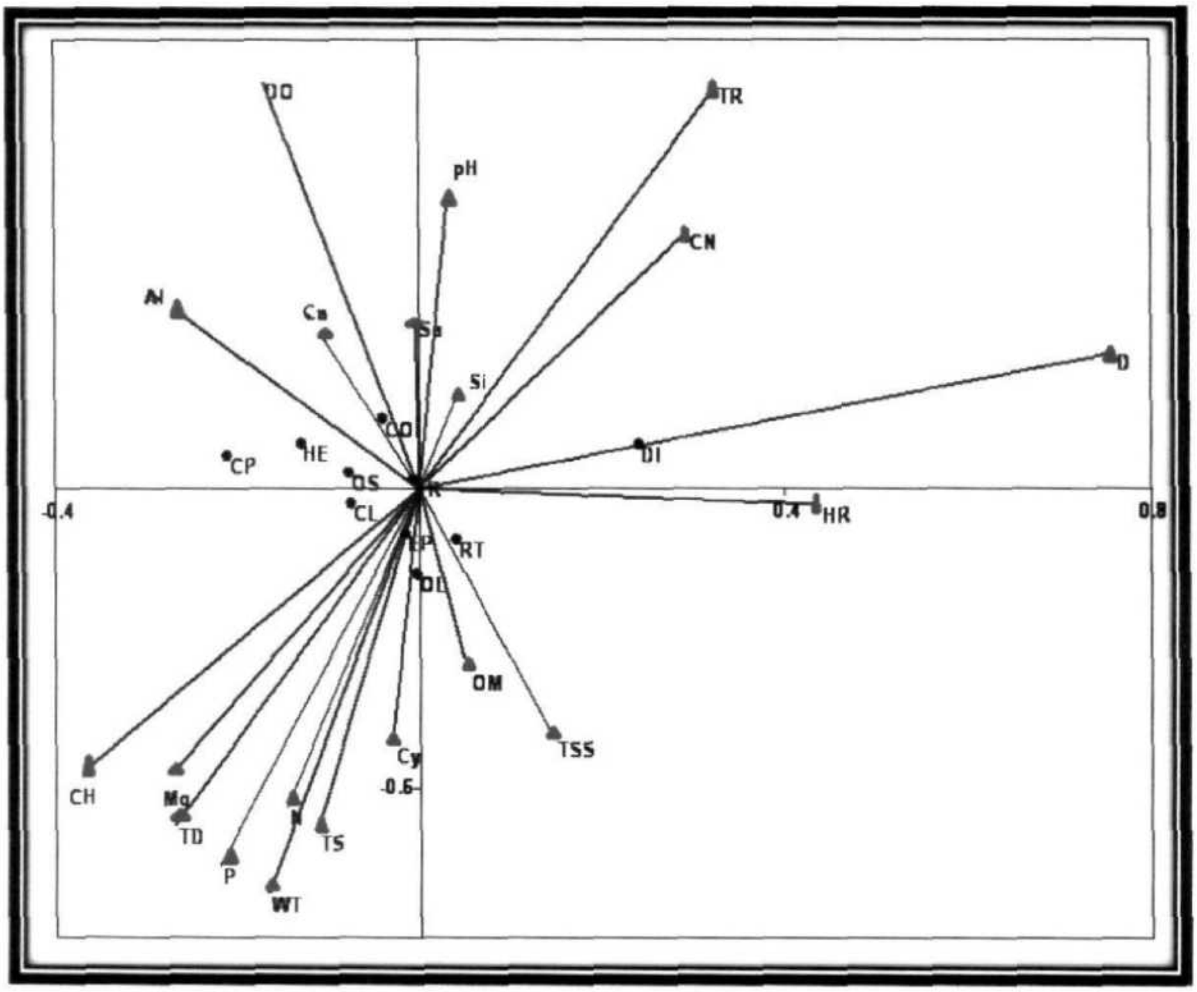


Fig.34: Line diagram showing variations in (A) benthos density (No./m^2), (B) D.O., (C) pH and (D) water temperature during study period in Medical Pond, Laldiggi Pond and Chautal Pond



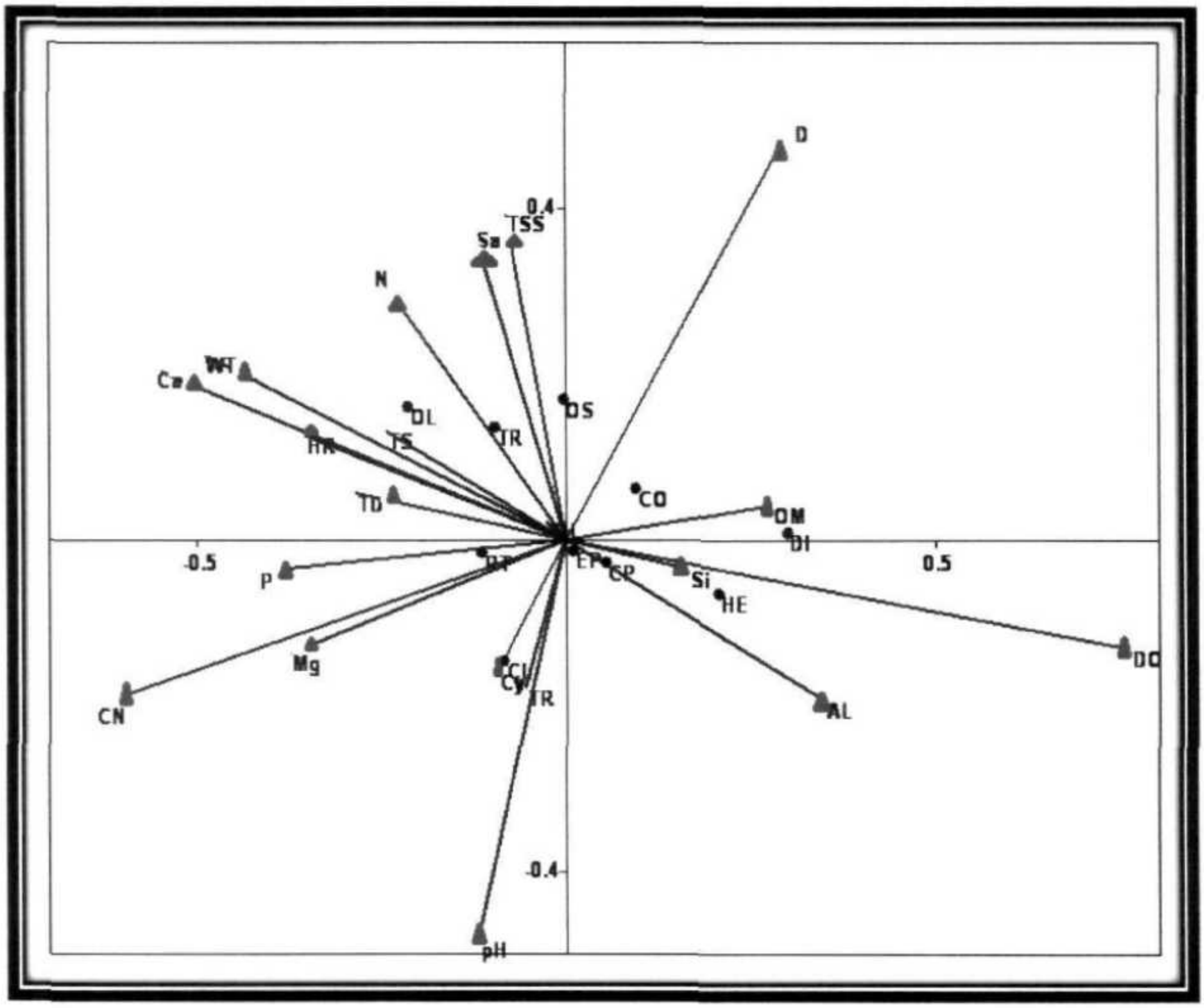
Axis	Eigenval	p	%
1	0.01699	0.3069	40.35
2	0.007541	0.1584	17.91
3	0.006264	0.08911	14.88
4	0.005375	0.3861	12.77

Fig. 35: Canonical correspondence analysis (CCA) diagram of 20 environmental parameters (Water temperature-WR, pH-pH, Dissolved-oxygen- DO, Nitrate-N, Phosphate-P, Alkalinity-AL, Hardness-HR, Calcium-Ca, Magnesium-Mg, Transparency-TR, Chloride-CH, Conductivity-CN, Depth-D, Total dissolved solids-TD, Total suspended solids-TSS, Total solids-TS, % organic matter-OM, composition of Sand-Sa, Silt-Si, Clay-Cy) and 10 benthic groups(Cladocera-CL, Copepoda-CP, Ostracoda-OS, Rotifera-RT, Oligochaeta-OL, Diptera-DI, Coleoptera-CO, Hemiptera-HE, Trichoptera- TR and Ephemeroptera-EP) in Medical Pond.



Axis	Eigenval	p	%
1	0.01843	0.3564	46.23
2	0.008716	0.2673	21.87
3	0.00557	0.9307	13.98
4	0.003323	0.5149	8.336

Fig. 36: Canonical correspondence analysis (CCA) diagram of 20 environmental parameters (Water temperature-WR, pH-pH, Dissolved-oxygen- DO, Nitrate-N, Phosphate-P, Alkalinity-AL, Hardness-HR, Calcium-Ca, Magnesium-Mg, Transparency-TR, Chloride-CH, Conductivity-CN, Depth-D, Total dissolved solids-TD, Total suspended solids-TSS, Total solids-TS, % organic matter-OM, composition of Sand-Sa, Silt-Si, Clay-Cy) and 10 benthic groups(Cladocera-CL, Copepoda-CP, Ostracoda-OS, Rotifera-RT, Oligochaeta-OL, Diptera-DI, Coleoptera-CO, Hemiptera-HE, Trichoptera- TR and Ephemeroptera-EP) in Laldiggi Pond.

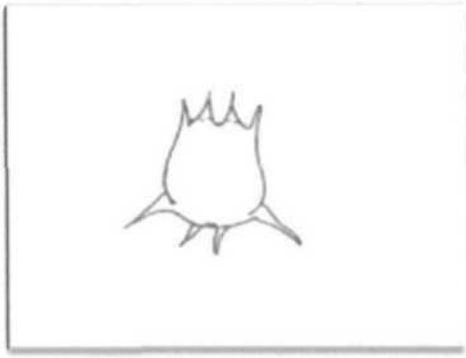


Axis	Eigenval	p	%
1	0.02536	0.2277	50.48
2	0.009174	0.9208	18.26
3	0.006528	0.505	12.99
4	0.004585	0.2475	9.127

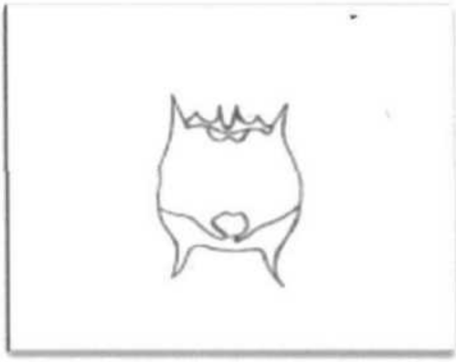
Fig. 37: Canonical correspondence analysis (CCA) diagram of 20 environmental parameters (Water temperature-WR, pH-pH, Dissolved-oxygen- DO, Nitrate-N, Phosphate-P, Alkalinity-AL, Hardness-HR, Calcium-Ca, Magnesium-Mg, Transparency-TR, Chloride-CH, Conductivity-CN, Depth-D, Total dissolved solids-TD, Total suspended solids-TSS, Total solids-TS, % organic matter-OM, composition of Sand-Sa, Silt-Si, Clay-Cy) and 10 benthic groups(Cladocera-CL, Copepoda-CP, Ostracoda-OS, Rotifera-RT, Oligochaeta-OL, Diptera-DI, Coleoptera-CO, Hemiptera-HE, Trichoptera- TR and Ephemeroptera-EP) in Chautal Pond.

Plates

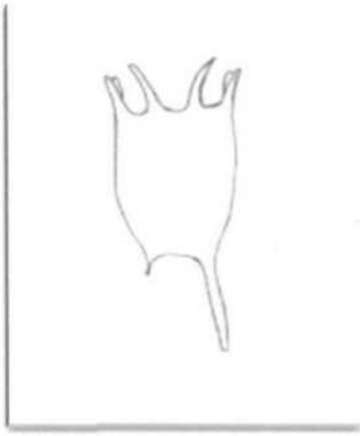
ROTIFERA



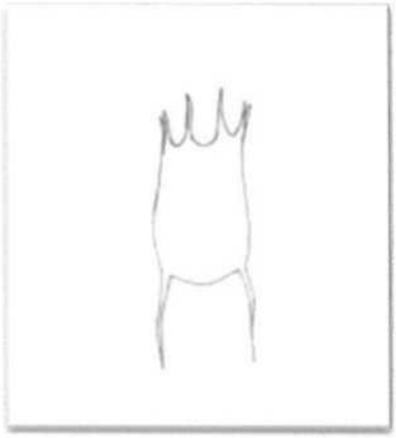
Brachionus calyciflours



Brachionus bidentata

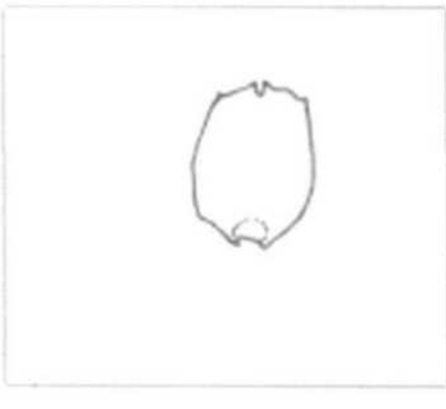


Keratella tropica



Keratella quadrata

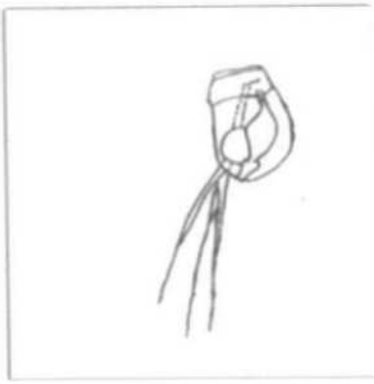
Asplanchna priodonta



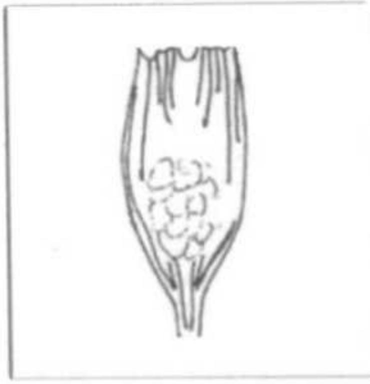
Brachionus angularis

Plate I

ROTIFERA

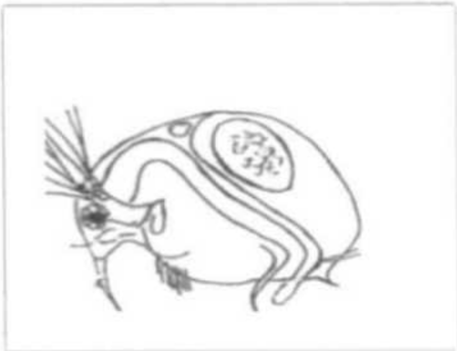


Filinia longiseta

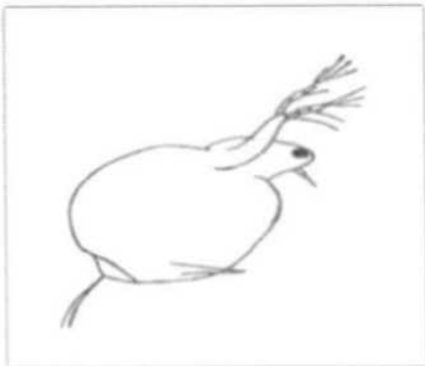


Notholca

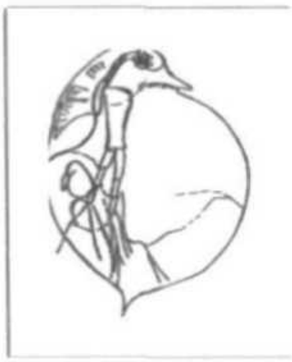
CLADOCERA



Bosmina sp.



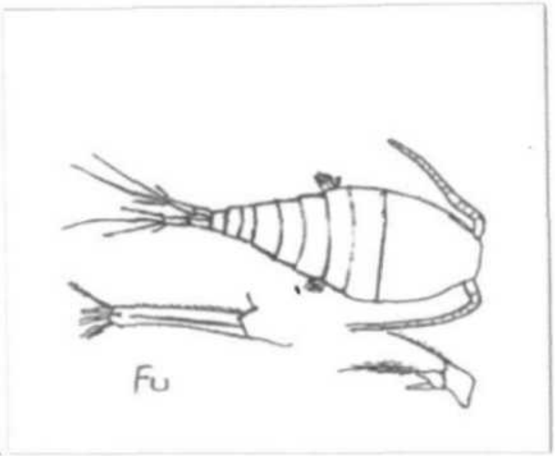
Moina micrura



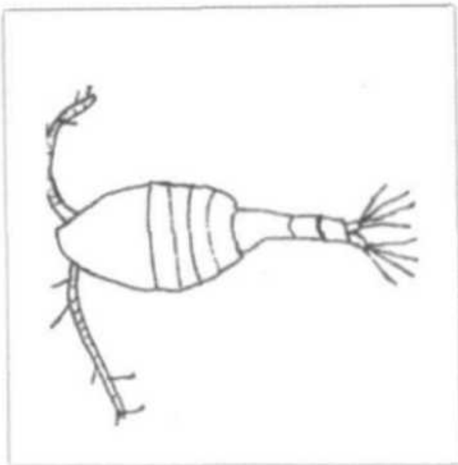
Daphnia pulex

Plate II

COPEPODA

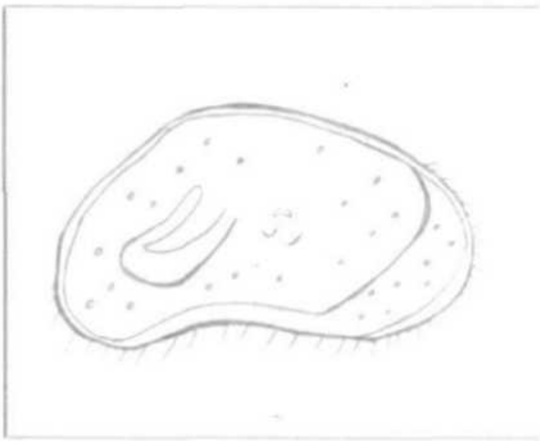


Cyclops viridis

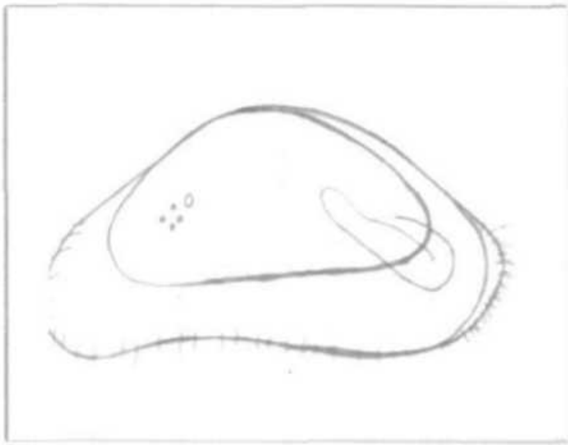


Diaptomus

OSTRACODA



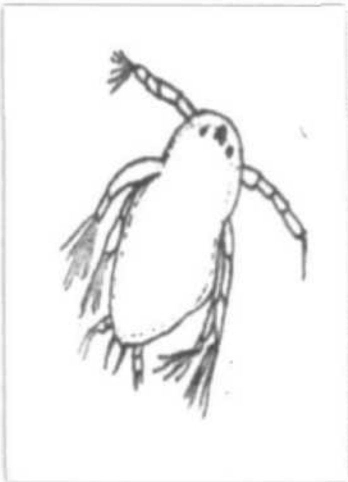
Stenocypris



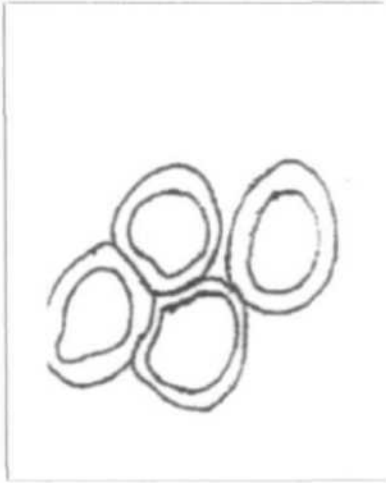
Heterocypris

Plate III

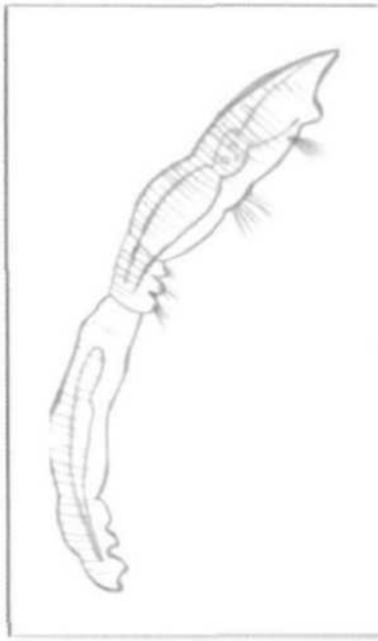
OLIGOCHAETA



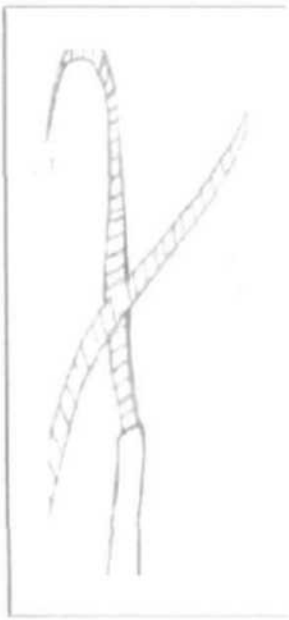
Naupli



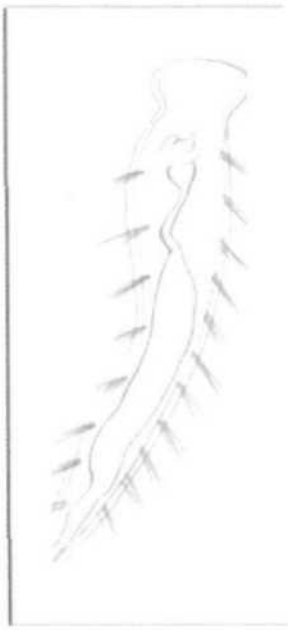
Eggs



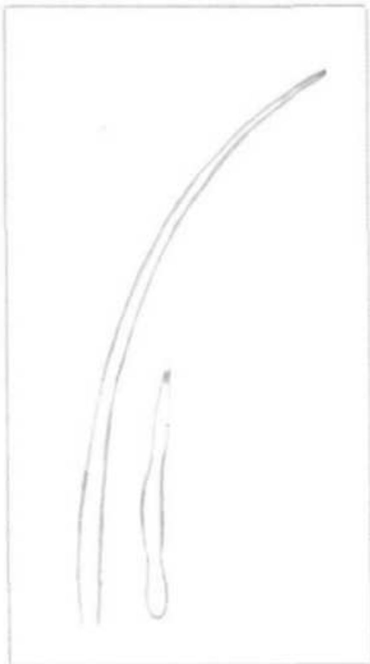
Chaetogaster



Tubifex



Aelosoma

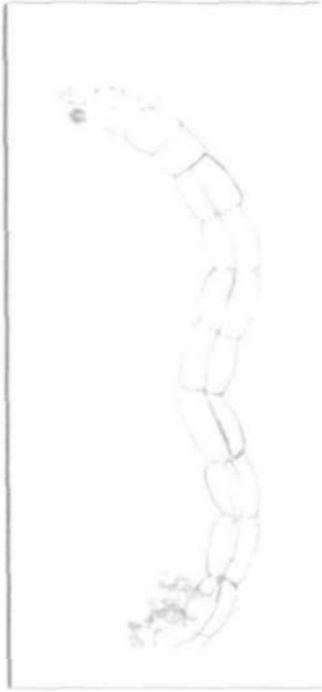


Nais

Plate IV

DIPTERA

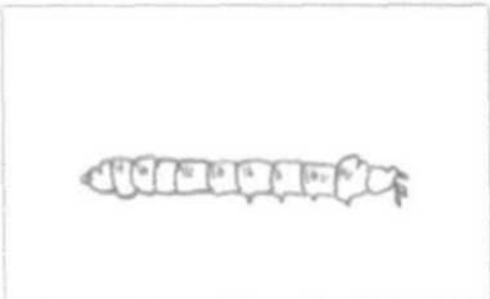
Pentanura



Chironomus Larva

Chironomus pupa

Culex Larva

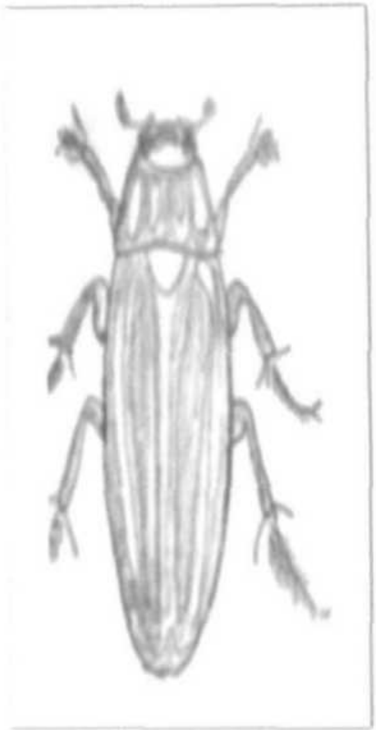


Helius Larva

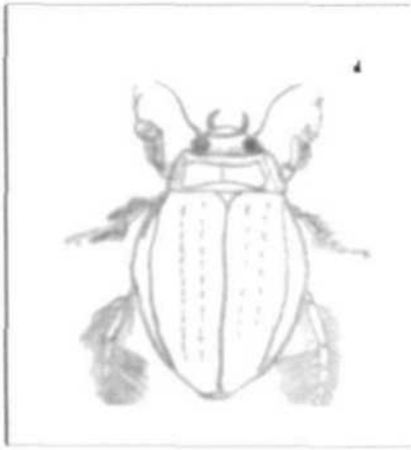
Plate V

COLEOPTERA

Berosus



Hydrophilus

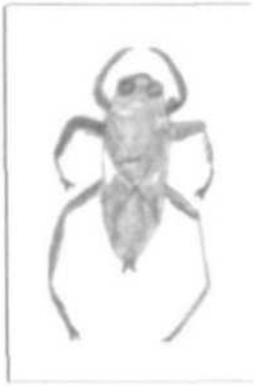


Dytiscus

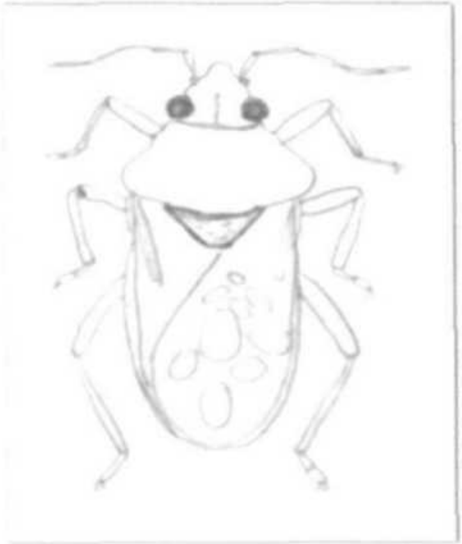
Haliplus

Plate VI

HEMIPTERA



Notonecta

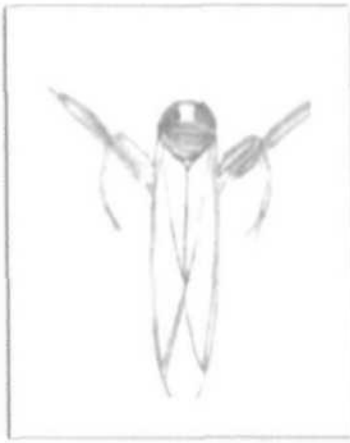


Hebrus

Hesperocorix

Belostoma

Sigara



Coroxid

Plate VII

TRICHOPTERA

Limnephilus larva

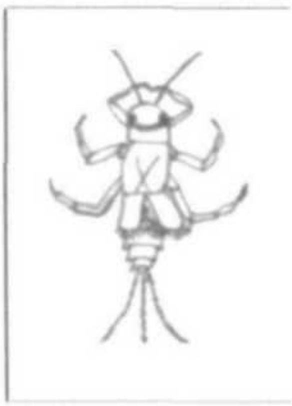
Polycentropus

Phryganaea larva

Plate VIII

EPHEMEROPTERA

Baetis hiemalis



Caenis nymph

Plate IX

Chapter VI

Conclusions

CONCLUSIONS

- In all the three selected ponds, water temperature was always found to be less than air temperature and followed the trend of air temperature. A positive significant correlation between air and water temperature was observed.
- Wide seasonal fluctuations were recorded in the depth in all the three selected ponds which might be related to increased evaporation at high temperature and precipitation.
- Higher values of dissolved oxygen content in winter could be related to increased oxygen retention capacity of water and reduction in respiratory consumption of oxygen due to reduced metabolic rate, while lower values during summer might be due to death and decomposition of organic matter, increasing water temperature leading to decrease in oxygen retention capacity of water and increase in the respiratory consumption of oxygen due to increased metabolic rate.
- Carbon dioxide was recorded absent in Medical Pond throughout the study period. The absence of free CO_2 in present study might be attributed to active photosynthesis. Moreover, phytoplankton and macrophyte combine bicarbonate to form carbon dioxide for photosynthesis and carbonates are released (Wurts and Durborow, 1992) while presence of Carbon dioxide in Laldiggi Pond and Chautal Pond might be related to lower rates of photosynthesis and higher rates of decomposition of organic matter.
- Carbonates were completely absent in Chautal Pond and for the most of the study period in Laldiggi Pond, which could be due to the presence of free CO_2 during this period, whereas it was found present in Medical Pond throughout study period.
- Bicarbonate alkalinity was recorded in all the Ponds except Medical Pond, where it was found absent during February and March, 2009.
- High values of pH were recorded in all the selected ponds throughout the course of study, which might be related to enhanced photosynthesis carried out by phytoplankton and macrophytes, wherein CO_2 is removed, and hence pH is raised.

- Higher values of hardness recorded throughout the study period in all the three selected ponds, might be due anthropogenic activities in and around these water bodies in addition of incoming sewage.
- High values of calcium recorded in all the three selected ponds could be attributed to heavy input of sewage from surrounding area and weathering of calcareous materials.
- Lower values of magnesium recorded during winter in all the three selected might be attributed to its sedimentation leading to settlement in the bottom and utilization by plankton, whereas higher values during summer months were related to higher evaporation rate and decomposition of organic matter.
- Higher values of chloride during summer in all selected ponds might be due to the higher rate of evaporation and organic pollution of animal origin, whereas lower values during winter could be related to reduction in siltation or allochthonus import of chloride along with rain water from catchment area.
- Higher values of NO_3-N recorded during monsoon in the selected ponds could be related to influx of decaying organic matter, nitrates from the catchment area and sewage contamination, whereas lower values in winter could be attributed to reduced rate of decomposition and its utilization by macrophytes.
- Higher values of PO_4-P during summer could be related to increased decomposition at higher temperature, release of nutrients and evaporation of water at high temperature, whereas lower values could be attributed to its utilization by macrophytes and algae for their growth, low calcium level and low temperature.
- Benthic fauna of these water bodies comprised of ten groups, Rotifera, Diptera,

  Cladocera,Ostracoda,Hemiptera,Oligochaeta,Coleoptera,Copepoda,Trichoptera, Ephemeroptera.
- Rotifera formed the first most abundant group of benthic fauna and was represented by *Brachionus, Keratella, Asplanchna, Filinia, Notholca and Hexarthra.*

- Rotifera exhibits high tolerance to eutrophic conditions, showing significant increase in abundance in response to anthropogenic organic enrichment and consequent water quality deterioration. Thus, considered a reliable environmental indicator. Further, the presence of this group in high density indicates the eutrophic nature of these water bodies.
- Diptera formed the second abundant group of benthic fauna in Medical Pond and Laldiggi Pond and third in Chautal Pond and was represented by *Chironomus, Culex, Pentanura, Helius.*
- *Chironomus* is one of the most common indicators of pollution. It can survive in low oxygen as well as polluted condition of water body. Its presence in high number in these water bodies indicated that these water bodies are polluted.
- The Cladocera formed the third abundant group in Medical Pond and Laldiggi Pond, whereas second in Chautal Pond and was represented by *Daphnia, Bosmina, Moina.* Ostracoda formed fifth abundant group in Medical Pond, sixth in Laldiggi Pond and fourth in Chautal Pond and was represented by *Heterocypris, Stenocypris and* Centrocypris *sp.*
- The Hemiptera formed sixth abundant group in Medical Pond, fifth in Laldiggi Pond and Seventh in Chautal Pond. This group was represented by the *Belostoma, Coroxid, Hebrus, Hesperocorixa, Notonecta insulata and Sigara.*
- The high or low abundance of Hemiptera in present study can be related to presence of macrophytes in these selected ponds.
- Coleoptera formed fourth abundant group in Medical Pond, eighth in Laldiggi Pond and seventh in Chautal Pond. This group was represented by *Berosus* larva, *Dystiscus* sp., *Haliplus* sp., *Hydrophilus* larva.
- The dominance of Coleopteran during summer in present study in all the three ponds could be related to the availability of food and vegetation which enhanced the growth of insects during this period.
- The Copepoda formed seventh abundant group in Medical Pond, fourth in Laldiggi Pond and eighth in Chautal Pond. This group was represented by *Cyclops and Diaptomus.* Continuous occurrence of egg bearing females, nauplii and copepodite stages, as found in almost all the months of

investigation periods, showed the prolific breeding nature without being affected by environmental factors.

- Oligochaeta formed eighth abundant group in Medical Pond, seventh in Laldiggi Pond and sixth in Chautal Pond. Oligochaeta group was represented by *Tubifex, Chaetogaster, Nais and Aelosma.*
- Trichoptera formed ninth and second least abundant group of benthic fauna in all Ponds. This group was represented by *Limnephilus* larva, *Phryganea* larva, *Polycentropus* larva.
- Trichopterans showed low frequency across selected ponds. This clearly indicated that they are sensitive to pollution. It can be further concluded that these insects can live in polluted water which can be related to the availability of food and oxygen in these ponds in addition to other factors.
- Ephemeropterans formed tenth and least abundant group in all the selected water bodies. This group was represented by *Baetis hiemalis* nymph and *Caenis* nymph.
- Mayfly larvae were recorded in all studied water bodies. Their presence indicated that these larvae are able to survive in polluted waters provided there is sufficient oxygen (> 2.8 mg/l).
- Due to eutrophic nature of Dipteran larvae, they have been used as reliable indicators of organic pollution and related perturbation. The high abundance of *Chironomus* sp. at all the selected ponds in present study indicates that these water bodies are highly eutrophic.
- Aquatic Hemiptera holds an important place in the ecology of fresh water ecosystems. Hemipterans are exceedingly important in relation to fish production. They are the primary food for many wild and cultivable fishes, which make them valuable predators, are also occasional pests in the manmade nursery ponds for fish culture where they feed on young fish. Certain families of bugs may be utilized in the biological control of mosquito larvae.
- Shannon-Weiner diversity index in the present study was recorded in the range 2.938 – 3.295 in the selected water bodies; they can be considered as moderately polluted.

- The value of Menhinick's index value ranged between 0.477 - 0.786 in all the waterbodies during study period.
- The Species evenness lies in the range 0.544 - 0.726 in all the waterbodies during study period. Moreover, diversity and evenness followed the same trend in all the three selected water bodies. High diversity was always associated with high evenness. Low diversity values were strongly affected by the most abundant species. Diversity was reduced to minimal levels by competitive exclusion or some other biotic interaction that can result in steady state assemblage.
- The value of Percentage similarity ranged between 75.96 - 91.67 in all the waterbodies during study period.
- Overall high Similarity index values suggest that most of the species in these ponds were common during the course of study. This has resulted in overlapping of faunal grouping and predictability of community composition.
- Benthic forms are an important component of food chains and energy flow pathways. Benthic community constitutes an important part of animal production within these ponds and is tightly integrated into the structure and functioning of these habitats (e.g. organic matter processing, nutrient retention, food resources for vertebrates, such as amphibians, fish or birds).
- Benthic organisms are often good indicators; insects mostly sensitive to water pollution are the Ephemeropterans (may flies), Plecopterans (stone fly) and Trichopterans (caddisfly). The sparse distribution, low numerical abundance and low species diversity in present study is therefore, indicate that these ponds have been severely disturbed.

Chapter VII

Summary

SUMMARY

The present investigation includes study of benthic diversity in relation to limnological parameters in some derelict water bodies of Aligarh. Three freshwater bodies namely, Medical Pond, Laldiggi Pond and Chautal Pond situated in Aligarh were selected. The samples of water and sediment, for investigation of various physicochemical parameters and for qualitative and quantitative study of benthic community, were collected, on monthly intervals from February, 2009 to January, 2010. The water sample were analysed for Temperature, Electrical conductivity, pH, free CO_2, Alkalinity, DO., Total hardness, Phosphate, Nitrate, Calcium, Magnesium and Chloride. Sediment samples were used for the analysis of sediment pH, Alkalinity, Sediment texture, Organic matter, and Organic carbon. Benthic community structure was subjected to analysis of various measures of diversity such as species diversity, evenness, similarity.

Temperature: Air temperature fluctuated from a minimum of 15°C in of January, 2010 to a maximum of 36°C in July, 2009 in Medical Pond. In Laldiggi Pond, it ranged from a minimum of 15°C in January, 2010 to a maximum of 36°C in June, 2009. In Chautal Pond, it varied from a minimum of 16°C in January, 2010 to a maximum of 37°C in June, 2009.

In Medical Pond water temperature fluctuated from a minimum of 14°C in January, 2010 to a maximum of 34°C in the months of July, 2009. In Laldiggi Pond, it varied from minimum of 12°C in January, 2010 to a maximum of 33°C in June, 2009. In Chautal Pond, it ranged from a minimum of 13°C in January, 2010 to a maximum of 34°C in June, 2009.

Water temperature recorded a very significant positive correlation with Air temperature (Medical Pond:r =0.996; Laldiggi Pond: r = 0.985; Chautal Pond: r = 0.995, with total solids (Medical Pond: r = 0.758; Laldiggi Pond r = 0.907; Chautal Pond: r= 0.746) and total dissolved solids (Medical Pond : r = 0.542; Laldiggi Pond: r = 0.931; Chautal Pond: r = 0.689) in all the selected water bodies.

Depth: Medical Pond showed the minimum depth 41.0 cm in June, 2009 and maximum of 169.0 cm in August, 2009. In Laldiggi Pond, it fluctuated from a minimum of 57.0 cm in June, 2009 to a maximum of 149.0 cm in September, 2009. In Chautal Pond, depth varied from a minimum of 51.0 cm in June, 2009 to a maximum of 99.0 cm in September, 2009.

Seasonal fluctuations in depth were found to be affected by high rate of evaporation at high ambient temperature and precipitation during rainy season.

Transparecy: Secchi disc transparency values varied from a minimum of 17.50 cm in June, 2009 to a maximum of 45.0 cm in March, 2009 in Medical Pond. Laldiggi Pond showed a range from 20.0 cm to 57.50 cm with minimum values recorded in June, 2009 and maximum in February, 2009. In Chautal Pond, the transparency values fluctuated from a minimum of 25.0 cm in June, 2009 to a maximum of 47.0 cm in March, 2009. Low values of transparency were recorded in summer and monsoon, which might be due to entry of suspended and colloidal matter, silt and clay into these water bodies along with the rain water from surrounding areas during monsoon and due to evaporation of water, which causes concentration of dissolved solids due to high temperature and production of plankton during summer. High transparency in post monsoon, winter and post winter might be related to low biological activities and settling of suspension Transparency recorded negative correlation with TDS (Medical Pond: r = - 0.472; Laldiggi Pond: r = - 0.610; Chautal Pond: r = - 0.499) and with water temperature (Medical Pond: r = - 0.768; Laldiggi Pond: r = - 0.641; Chautal Pond: r = - 0.745) in all the three selected water bodies.

D.O.: The value of dissolved oxygen fluctuated from a minimum of 3.6 mg/l in July, 2009 to a maximum of 10.0 mg/l in December, 2009 in Medical Pond. Laldiggi Pond, showed variations from a minimum of 3.1 mg/l in October, 2009 to a maximum of 8.0 mg/l in January, 2010. In

Chautal Pond, it ranged from a minimum of 3.0 mg/l in July, 2009 to a maximum of 8.2 mg/l in January 2010. The higher values of dissolved oxygen content in winter could be related to high oxygen retention capacity of water at low temperature and reduction in respiratory consumption of oxygen due to reduced metabolic rate, whereas lower values during summer might be due to death and decomposition of organic matter, decrease in oxygen retention by water at high temperature and increase in the respiratory consumption of oxygen due to increased metabolic rate. Statistically D.O. showed negative and significant correlation with water temperature in all the three selected ponds (Medical Pond: $r = -0.853$; Laldiggi Pond: $r = -0.811$ and Chautal Pond: $r = -0.577$), indicating temperature as one of the important factors for variations in D.O. concentration in all the water bodies.

Free CO_2 Carbon dioxide was recorded absent in Medical Pond throughout the study period. The absence of free CO_2 in present study might be attributed to active photosynthesis. Moreover, phytoplankton and macrophyte combine bicarbonate to form carbon dioxide for photosynthesis and carbonates are released (Wurts and Durborow, 1992). In Laldiggi Pond, the carbon dioxide was found to be absent in some months viz. September, 2009, November, 2009,December, 2009 and January, 2010 and during rest of the period of study, it fluctuated from a minimum of 18.0 mg/l in March, 2009 to a maximum of 30.0 mg/l in August, 2009. In Chautal Pond, it varied from a minimum of 10.0 mg/l in February, 2009 to a maximum of 45.0 mg/l in August, 2009. The presence of carbon dioxide in these ponds could be attributed to lower rates of photosynthesis and more decomposition of organic matter in these water bodies.

Conductivity: Laldiggi Pond showed the minimum values of 978 μScm^{-1} in June, 2009 to a maximum of 1678 μScm^{-1} in January, 2010. In Chautal Pond, values of conductivity fluctuated from a minimum of 998 μScm^{-1} in December, 2009 to a maximum of 1691 μScm^{-1} in May, 2009. Higher values of conductivity in Medical and Chautal Pond were recorded during summer which might be related to decomposition of organic matter, fecal matter, sewage, leaching of salts etc. from the catchment area, whereas in Laldiggi Pond, lower values during summer might be attributed to increase in the uptake of nutrients by algae and macrophyte in this pond.

TS: Medical Pond showed the minimum value 1526 mg/l in January, 2010 and maximum 2900 mg/l in August, 2009. In Laldiggi Pond, values fluctuated from a minimum of 1400 mg/l in December, 2009 to a maximum of 2970 mg/l in July, 2009. Chautal Pond Showed the minimum value 1210 mg/l in December, 2009 and maximum 3050 mg/l in September, 2009. Statistically total solids recorded a very significant positive correlation with water temperature in all the three selected ponds (Medical Pond: r = 0.758; Laldiggi Pond: r =0.907 and Chautal Pond: r = 0.746), indicating temperature as one of the important factors responsible for concentration of solids.

TSS: Medical Pond showed minimum value 450 mg/l in June, 2009 and maximum 950 in August, 2009. In Laldiggi Pond, it fluctuated from a minimum of 340 mg/l in November, 2009 to a maximum of 1200 mg/l in August, 2009. Chautal Pond showed minimum value of 395 mg/l in February, 2009 and maximum 915 mg/l in September, 2009. Statistically TSS showed negative correlation with transparency (Medical Pond: r =- 0.187; Laldiggi Pond: r =-0.262; Chautal Pond: r =- 0.569.

TDS: Medical Pond showed minimum value 920 mg/l in December, 2009 and maximum 2010 mg/l in September, 2009. In Laldiggi Pond, TDS values fluctuated from a minimum of 950 mg/l in December, 2009 to a maximum of 2200 mg/l in June, 2009. In Chautal Pond, values varied from a minimum of 700 mg/l in November, 2009 to a maximum of 2135 mg/l in September, 2009. Statistically TDS showed negative correlation with dissolved oxygen in Laldiggi Pond (r =-0.631) and Chautal Pond (r =-0.446) but in Medical Pond, it showed positive correlation (r =0.510). TDS showed positive significant correlation with water temperature (Medical Pond: r = 0.542; Laldiggi Pond: r =0.931;

Chautal Pond: r =0.689). With the increase in temperature the decomposition and mineralization processes increase, releasing nutrient in the water.

pH: It varied from a minimum of 8.5 in January, 2010 to a maximum of 9.5 in July, 2009 in Medical Pond. In Laldiggi Pond, it fluctuated from a minimum of 8.0 in April, 2009 to a maximum of 8.9 in December, 2009. In Chautal Pond, it ranged from a minimum of 7.8 in September, 2009 to a maximum of 8.5 in April, 2009. pH of sediment fluctuated from 7.5 to 9.6 throughout the course of study. In Medical Pond, it varied from a minimum of 8.4 in December, 2010 to a maximum of 9.6 in June, 2009. In Laldiggi Pond, it fluctuated from a minimum of 8.0 in July, 2009 to a maximum of 9.2 in December, 2009. In Chautal Pond, it ranged from a minimum of 7.5 in September, 2009 to a maximum of 8.7 in April, 2009. The high pH values in present study could be related to enhanced photosynthesis carried out by phytoplankton and macrophytes, wherein CO_2 is removed and, hence pH is raised. Statistically pH showed positive correlation with total alkalinity in Medical Pond (r = 0.783) and Chautal Pond (r = 0.203) and negative significant correlation in Laldiggi Pond (r =- 0.635).

Total alkalinity: Values of total alkalinity fluctuated from a minimum of 180.00 mg/l in March, 2009 to a maximum of 590.00 mg/l in May, 2009 in Medical Pond. Laldiggi Pond, showed the minimum value 145.00 mg/l in October, 2009 and maximum 500.00 mg/l in April, 2009. In Chautal Pond, the values varied from a minimum of 250.00 mg/l in September, 2009 to a maximum of 407.00 mg/l in November, 2009. Variations in total alkalinity of sediment ranged from 64.55 mg/l to 228.00 mg/l in the selected water bodies. In Medical Pond, values of total alkalinity fluctuated from a minimum of 84.55 mg/l in November, 2009 to a maximum of 228.76 mg/l in June, 2009. In Laldiggi Pond, it showed the minimum value 73.20 mg/l in September, 2009 and maximum 201.33 mg/l in April, 2009. In Chautal Pond, the values varied from a minimum of 64.55 mg/l in November, 2009 to a maximum of 178.00 mg/l in May, 2009. Statistically alkalinity showed positive correlation with Hardness in Medical Pond (r = 0.447) and Chautal Pond (r = 0.365) and negative correlation in Laldiggi Pond (r = -0.309).

Carbonate alkalinity: Medical Pond showed minimum value 100.00 mg/l in October, 2009 and maximum 500.00 mg/l in June, 2009, whereas in Laldiggi Pond, carbonate alkalinity was recorded in September, 2009, November, 2009, December, 2009 and January, 2010 only. Its values fluctuated from a minimum of 100.00 mg/l in December, 2009 to a maximum of 160.00 mg/l in January, 2010. In Chautal Pond, it was never recorded during the study period.

Bicarbonate alkalinity: The values of bicarbonate alkalinity fluctuated from a minimum of 50.00 mg/l in September, 2009 to a maximum of 110.00 mg/l in May and August, 2009 and in February, 2009 and March, 2009 it was not found in Medical Pond. In Laldiggi Pond, it showed the minimum value 20.00 mg/l in September, 2009 and maximum 560.00 mg/l in April, 2009. In Chautal Pond, it varied from a minimum of 250.00 mg/l in September, 2009 to a maximum of 407.00 mg/l in November, 2009.

Hardness: Medical Pond showed minimum value 124.00 mg/l during January, 2010 and maximum 260.00 mg/l in April, 2009. Laldiggi Pond, showed minimum hardness 112.00 mg/l in December, 2009, and maximum 170.00 mg/l in July, 2009. Chautal Pond showed minimum values of hardness 100.00 mg/l during February, 2009 and maximum 240.00 mg/l in November, 2009. Higher values of hardness during summer in all the ponds might be attributed to high evaporation of water at high temperature and anthropogenic activities in and around these ponds.

Calcium: It fluctuated from a minimum of 36.87 mg/l in December, 2009 to a maximum of 64.12 mg/l in May, 2009 in Medical Pond. In Laldiggi Pond, it varied from a minimum of 36.00 mg/l in December, 2009 to a maximum of 89.77 mg/l in February, 2009. In Chautal Pond, it fluctuated from a minimum of 48.00 mg/l in December, 2009 to a maximum of 88.17 mg/l in March, 2009. High values of calcium were recorded throughout the study period which might be attributed to continuous input of sewage from surrounding areas and weathering of calcareous materials.

Magnesium: It fluctuated from a minimum of 19.77 mg/l in October, 2009 to a maximum of 43.51 mg/l in May, 2009 in Medical Pond. In Laldiggi Pond, it varied from a minimum of 18.46 mg/l in January, 2010 to a maximum of 36.92 mg/l in April, 2009. In Chautal Pond, it ranged from a minimum of 15.82 mg/l in January, 2010 to a maximum of 34.28 mg/l in June, 2009. Lower values during winter months might be attributed to higher sedimentation rate leading to settlement in the bottom and utilization by plankton, whereas higher values during summer can be related to higher evaporation leading to concentration and decomposition of organic matter.

Chloride: It fluctuated from a minimum of 127.00 mg/l in the month of January, 2010 to a maximum of 624.0 mg/l in the month of June, 2009 in Medical Pond. It ranged from a minimum of 93.70 mg/l in the month of December, 2009 to a maximum of 244.00 mg/l in June, 2009 in Laldiggi Pond. In Chautal Pond, values fluctuated from a minimum of 135.00 mg/l in February, 2009 to a maximum of 227.00 mg/l in June, 2009. Maximum values during summer might be due to higher rate of evaporation and organic pollution of animal origin, whereas lower values during winter could be related to reduction in siltation or allochthonous import of organic matter from catchment area. Moreover, Medical Pond showed relatively high chloride content than that of Laldiggi Pond and Chautal Pond, which might be due to increased sewage contaminations and public use for washing purposes. Statistically chloride showed positive and significant correlation with water temperature (Medical Pond: $r = 0.550$; Laldiggi Pond: $r = 0.778$; Chautal Pond: $r = 0.546$).

Nitrate-nitrogen: It fluctuated from a minimum of 0.054 mg/l in January, 2010 to a maximum of 0.195 mg/l in August, 2009 in Medical

Pond. Laldiggi Pond, showed the minimum value 0.081 mg/l in January, 2010 and maximum 0.195 mg/l in June, 2009. In Chautal Pond, values fluctuated from a minimum of 0.051 mg/l in January, 2010 to of maximum 0.278 mg/l in September, 2009.

Statistically NO_3-N recorded a significant positive correlation with water temperature (Medical Pond: r = 0.915; Laldiggi Pond r = 0.754; Chautal Pond: r = 0.686), and with TDS in all the three selected ponds (Medical Pond: r = 0.528; Laldiggi Pond: r = 0.781; Chautal Pond: r = 0.809). Higher values were recorded during Monsoon, which could be related to influx of decaying organic matter along with surface run-off from catchment area. Lower values of NO_3-N during winter could be attributed to reduced rate of decomposition and its utilization by macrophytes.

Phosphate-phosphorus: It ranged from a minimum of 0.419 mg/l in March, 2009 to a maximum of 1.040 mg/l in June, 2009 in Medical Pond. Laldiggi Pond, showed minimum value 0.226 mg/l in January, 2010 and maximum 0.965 mg/l in June, 2009. In Chautal Pond, it fluctuated from a minimum of 0.240 mg/l in December, 2009 to a maximum of 0.950 mg/l in May, 2009. Higher values of PO_4 - P during summer were found to be due to release of phosphates from decomposition at high temperature and evaporation of water leading to its high concentration, whereas lower values could be attributed to its utilization by macrophytes and algae for their growth, low calcium level and low temperature.

Statistically PO_4 -P recorded a significant positive correlation with water temperature in all the three selected ponds (Medical Pond: r = 0.730; Laldiggi Pond: r =0.875; Chautal Pond: r =0.739). It recorded negative correlation with pH in Laldiggi Pond (r = -0.694) and Chautal Pond (r =-0.037), whereas positive correlation in Medical Pond (r = 0.492).

%Organic carbon: It varied from 0.516% during May, 2009 to 2.270% during September, 2009 in Medical Pond. In Laldiggi Pond it ranged from 0.766% during January, 2010 to 2.488% during October, 2009, whereas in Chautal Pond the value fluctuated between 0.636% during March, 2009 and 3.375% during November, 2009.

%Organic matter: The highest value (5.820%) was observed on clay loam substratum in Chautal Pond and lowest (0.891%) on sandy clay loam substratum in Medical Pond. The organic matter in sediment of Medical Pond varied from 0.891% during May, 2009 to 3.914% during September, 2009, In Laldiggi Pond it ranged from 1.321% during January, 2010 and 4.290% during October, 2009, whereas in Chautal Pond the value fluctuated between 1.098% during March, 2009 and 5.820% during November, 2009.

On the basis of composition of sand, silt and clay in sediment, the type of sediment is sandy clay loam in Medical and Laldiggi Pond, whereas clay type in Chautal Pond.

Benthos, distribution abundance and diversity– The freshwater benthic fauna of these water bodies comprised of ten groups, namely *Rotifera, Oligochaeta, Cladocera, Copepoda, Ostracoda, Diptera, Hemiptera, Coleoptera, Trichoptera and Ephemeroptera.* They showed wide variations in their densities and occurrence.

Rotifera formed the first most abundant group of benthic fauna in all the three selected water bodies. This group was represented by six genera viz *Brachionus, Keratella, Notholca, Filinia, Hexarthra, and Asplanchna.* Total percent contribution of Rotifers ranged from 23.47 % during December, 2009 to 35.12 % during September, 2009 in Medical Pond, from 22.31 % during January, 2010 to 33.73 % in August, 2009 in Laldiggi Pond and from 24.83 % during September, 2009 to 41.45 % in March, 2009 in Chautal Pond.

Statistically Rotifera recorded a significant negative correlation with water temperature (Medical Pond: $r = -0.769$; Laldiggi Pond: $r = -0.618$; Chautal Pond: $r = -0.584$), whereas with D.O., it showed significant positive correlation in all the three selected Ponds (Medical Pond: $r = 0.599$; Laldiggi Pond: $r = 0.631$; Chautal Pond: $r = 0.566$). It showed negative correlation with TDS in all ponds (Medical Pond: $r = -0.171$; Laldiggi Pond: $r = -0.646$; Chautal Pond: r = -

0.782) and with diversity index in Medical Pond (r = -0.172) and Chautal Pond (r = -0.623), whereas positive in Laldiggi Pond (r = 0.243).

Diptera formed the second abundant group of benthic fauna in Medical Pond and Laldiggi Pond and third in Chautal Pond. It was represented by *Chironomus, Helius, Culex* and *Pentaneura*. The percent contribution of Diptera to the total benthos ranged from 8.39 % during August, 2009 to 23.31 % in May, 2009 in Medical Pond, from 6.52 % during June, 2009 to 25.28 % in October, 2009 in Laldiggi Pond and from 7.14 % during April, 2009 to 22.25 % in January, 2010 in Chautal Pond.

Statistically Diptera recorded a significant negative correlation with water temperature (Medical Pond: r = -0.654; Laldiggi Pond: r = -0.716; Chautal Pond: r = -0.655), TDS (Medical Pond: r = -0.538; Laldiggi Pond: r = -0.705; Chautal Pond: r = -0.535) and nitrate (Medical Pond: r = -0.570; Laldiggi Pond: r = -0.676; Chautal Pond; r= -0.643) in all the ponds.

Cladocera formed the third abundant group in Medical Pond and Laldiggi Pond whereas second in Chautal Pond. It was represented by species of *Daphnia, Bosmina* and *Moina*. Total percent contribution of cladocera was found to be ranged from 8.06 % during January, 2010 to 14.74 % in December, 2009 in Medical Pond, from 12.75 % during September, 2009 to 18.83 % in May, 2009 in Laldiggi Pond and from 10.49 % during August, 2009 to 22.63 % in April, 2009 in Chautal Pond.

Statistically Cladocera recorded significant negative correlation with water temperature (Medical Pond: r = -0.610; Laldiggi Pond: r = -0.647; Chautal Pond: r = -0.503), whereas it showed significant positive correlation with D.O. in all the three selected ponds (Medical Pond: r = 0.698; Laldiggi Pond: r = 0.854; Chautal Pond: r = 0.627). A negative significant correlation was obtained with T.D.S in Medical Pond (r = -0.622) and in Laldiggi Pond (r = -0.604) and insignificant in Chautal Pond (r= -0.298) and with diversity index, it showed positive correlation in Medical Pond (r = 0.464) and Laldiggi Pond (r = 0.259) and negative in Chautal Pond (r = -0.542).

Ostracoda formed fifth abundant group in Medical Pond, sixth in Laldiggi Pond and fourth in Chautal Pond. It was represented *Heterocypris, Stenocypris* and *Centrocypris*. Its percent contribution varied from 4.78 % during June, 2009 to 11.58 % in November, 2009 in Medical Pond, from 4.11 % during October, 2009 to 9.75 % in June, 2009 in Laldiggi Pond and from 7.01 % during February, 2009 to 15.18 % in March, 2009 in Chautal Pond. Statistically Ostracoda recorded negative correlation with water temperature (Medical Pond: r = -0.667; Laldiggi Pond: r = -0.595; Chautal Pond: r = -0.552) and with TDS in all the three selected Ponds (Medical Pond: r = -0.572; Laldiggi Pond: r = -0.516; Chautal Pond: r = -0.493).

Hemiptera formed sixth abundant group in Medical Pond, fifth in Laldiggi Pond and Seventh in Chautal Pond. Hemiptera was represented by *Notonecta, Coroxid, Hebrus, Sigara, Belostoma and Hespercorixa.* Total percent contribution of Hemiptera ranged from 4.28 % during October, 2009 to 12.88 % during December, 2009 in Medical Pond, from 4.93 % during October, 2009 to 12.57 % in December, 2009 in Laldiggi Pond and from 2.65 % during March, 2009 to 10.12 % in December, 2009 in Chautal Pond.

Statistically Hemiptera recorded a significant negative correlation with water temperature (Medical Pond: r = -0.712; Laldiggi Pond: r = -0.676; Chautal Pond: r = -0.596), whereas it showed significant positive correlation with D.O. in all the three selected Ponds (Medical Pond: r = 0.772; Laldiggi Pond: r = 0.889; Chautal Pond: r = 0.860). It showed negative correlation with TDS in all the three selected ponds (Medical Pond: r = -0.350; Laldiggi Pond: r = -0.552; Chautal Pond: r = -0.450) and with diversity index it showed insignificant negative correlation in Medical Pond (r = -0.188) and Chautal Pond (r = -0.088) but significant positive in Laldiggi Pond (r = 0.675).

Coleoptera formed fourth abundant group in Medical Pond, eighth in Laldiggi Pond and seventh in Chautal Pond. This group was represented by *Hydrophilus, Dysticus, Berosus* and *Haliplus*. The total percent contribution of Coleoptera to the overall density of benthic fauna ranged from 4.00 % during July, 2009 to 12.52 % in October, 2009 in Medical Pond, from 3.10 % during May, 2009 to 9.23 % in June, 2009, in Laldiggi and from 4.06 % during June, 2009 to 10.12

% during December, 2010 in Chautal Pond. Statistically Coleoptera recorded a significant negative correlation with water temperature (Medical Pond: r = -0.721; Laldiggi Pond: r = -0.741; Chautal Pond: r = -0.669), whereas significant positive correlation with D.O. (Medical Pond: r = 0.667; Laldiggi Pond: r = 0.825; Chautal Pond: r = 0.693) in all the three selected ponds. It showed negative correlation with TDS in all the three selected ponds (Medical Pond: r = -0.463; Laldiggi Pond: r = -0.481; Chautal Pond: r = -0.328) and with diversity index, it showed positive correlation in Medical Pond (r = 0.184) and Laldiggi Pond (r = 0.591) and negative in Chautal Pond (r = -0.201).

Copepods formed seventh abundant group in Medical Pond, fourth in Laldiggi Pond and eighth in Chautal Pond. It was represented by *Cyclops viridis and Diaptomus*. Total percent contribution of copepods ranged from 5.11 % during December, 2009 to 9.67 % in January, 2010 in Medical Pond, from 5.16 % during August, 2009 to 14.70 % in May, 2009 in Laldiggi Pond and from 2.82 % during June, 2009 to 7.39 % in October, 2009 in Chautal Pond.

Statistically Copepoda recorded significant negative correlation with water temperature (Medical Pond: r = -0.675; Laldiggi Pond: r = -0.543; Chautal Pond: r = -0.745), whereas, it showed significant positive correlation with D.O. (Medical Pond: r = 0.523; Laldiggi Pond: r = 0.662; Chautal Pond: r = 0.817) and insignificant negative correlation with TDS (Medical Pond: r = -0.306; Laldiggi Pond: r = -0.473; Chautal Pond: r = -0.292) in three selected pond. With diversity index, it showed insignificant negative correlation in Medical Pond (r = -0.267) and Chautal Pond (r = -0.126) whereas insignificant positive in Laldiggi Pond (r = 0.213).

Oligochaeta formed eighth abundant group in Medical Pond, seventh in Laldiggi Pond and sixth in Chautal Pond. This group was represented by *Tubifex, Chaetogaster, Nais and Aelosma*. The total percent contribution of Oligochaeta to the overall density of benthic fauna ranged from 4.53 % during February, 2009 to 8.87 % in September, 2009 in Medical Pond, from 4.63 % during February, 2009 to 9.13 % in June, 2009, in Laldiggi and from 4.02 % during December, 2009 to 10.78 % during July, 2009 in Chautal Pond. Statistically Oligochaeta recorded negative correlation with water temperature

(Medical Pond: r = -0.187; Laldiggi Pond: r = -0.180; Chautal Pond: r = -0.527), whereas it showed positive correlation with D.O. in all the three selected ponds (Medical Pond: r = 0.435; Laldiggi Pond: r = 0.678; Chautal Pond: r = 0.133). It showed positive correlation with TDS in Laldiggi Pond (r = 0.318) and Chautal Pond (r = 0.309) and negative in Medical Pond (r = -0.457) and with diversity index it showed positive correlation in all studied ponds.

Trichoptera formed ninth and second least abundant group in all the three water bodies. This group was represented by *Limnephilus, Phryganaea* and *Polycentropus*. Total percent contribution of Trichoptera was found negligible and ranged from 0.138 % during April, 2009 to 0.350 % during December, 2009 in Medical Pond, from 0.106 % during April, 2009 to 0.347 % in June, 2009 in Laldiggi Pond and from 0.132 % during September, 2009 to 5.76 % in December, 2009 in Chautal Pond.

Statistically Trichoptera recorded a significant positive correlation with dissolved oxygen (Medical Pond: r = 0.846; Laldiggi Pond: r = 0.642; Chautal Pond: r = 0.560), whereas it showed significant negative correlation with water temperature Medical Pond (r = -0.757) and Laldiggi Pond (r = -0.555), whereas insignificant negative in Chautal Pond (r = -0.499). It showed negative correlation with TDS in all the three selected Ponds (Medical Pond: r = -0.493; Laldiggi Pond: r = -0.380; Chautal Pond: r = -0.596) and with diversity index in Medical Pond (r = -0.268) and Chautal Pond (r = -0.481) and positive in Laldiggi Pond (r = 0.354)

Ephemeroptera formed tenth and least abundant group in all the selected water bodies. This group was represented by *Baetis* and *Caenis*. Total percent contribution of Ephemeroptera was found fractional. It ranged from 0.069 % during April, 2009 to 0.378 % during September, 2009 in Medical Pond, from 0.077 % during March, 2009 to 0.189% in November, 2009 in Laldiggi Pond and from 0.065 % during March, 2009 to 0.231 % in November, 2009 in Chautal Pond.

Statistically Ephemeroptera recorded a significant negative correlation with water temperature (Medical Pond: r = -0.670; Laldiggi Pond: r = -0.647;

Chautal Pond: r = -0.565), whereas with D.O., it showed significant positive correlation in all the three selected Ponds (Medical Pond: r = 0.586; Laldiggi Pond: r = 0.783; Chautal Pond: r = 0.761).

Eggs and Nauplii were found throughout the period of investigation indicating that benthos are prolific and continuous breeders.

Diversity Indices

The benthos diversity index varied from a minimum of 3.11 in June, 2009 to a maximum of 3.23 in February, 2009 in Medical Pond, from 2.983 in October, 2009 to 3.208 in January, 2010 in Laldiggi Pond and from 3.002 in February, 2009 to 3.295 in August, 2009 in Chautal Pond. The diversity index indicates the order of pollution of a water body.

Benthos species diversity index showed insignificant negative correlation with water temperature in Medical Pond (r = -0.041) and Laldiggi Pond (r = -0.246), whereas significant positive in Chautal Pond (r = 0.544).

Correlation between benthos species Diversity and following group density are: Cladocera density showed insignificant positive correlation in Medical Pond (r = 0.464) and Laldiggi Pond (r = 0.259) and significant negative in Chautal Pond (r = - 0.542); Copepoda insignificant negative correlation in Medical Pond (r = - 0.267) and Chautal Pond (r = - 0.126) whereas insignificant positive correlation in Laldiggi Pond (r = 0.213); Rotifera insignificant in all ponds except Chautal Pond where it is insignificant negative (Medical Pond: r = - 0.172; Laldiggi Pond: r = 0.243 and in Chautal Pond: r = - 0.623); Ostracoda positive correlation in Medical Pond (r = 0.282) and Laldiggi Pond (r = 0.495) and negative in Chautal Pond (r = - 0.174); Diptera significant negative correlation in Medical Pond (r = - 0.534) and insignificant positive in Laldiggi Pond (r = 0.261) and insignificant negative in Chautal Pond (r = - 0.378); Hemiptera insignificant correlation in all the water bodies except Laldiggi Pond (Medical Pond: r = -0.188; Laldiggi Pond: r = 0.675; Chautal Pond: r = -0.088); Coleoptera insignificant positive correlation in all three ponds except Chautal Pond (Medical Pond: r = 0.184; Laldiggi Pond: r = 0.591, and Chautal Pond: r =

-0.201); Trichoptera insignificant negative correlation in Medical Pond (r = -0.268) and Chautal Pond (r = -0.481) and positive in Laldiggi Pond (r = 354); Ephemeroptera isignificant correlation in all the ponds (Medical Pond: r = 0.165; Laldiggi Pond: r = 0.441; Chautal Pond: r = -0.019).

Menhinicks index of diversity for benthos varied from a minimum of 0.553 in December, 2009 to a maximum of 0.786 in July, 2009 in Medical Pond, from 0.494 in January, 2010 to 0.723 in June, 2009 in Laldiggi Pond and from 0.477 in January, 2010 to 0.7048 in July, 2009 in Chautal Pond. Statistically benthos density showed significant negative correlation with Menhinicks index in all the studied water bodies (Medical Pond: r = -0.983; Laldiggi Pond: r = -0.982 and Chautal Pond: r = -0.931).

The species evenness values varied from a minimum of 0.644 in June, 2009 to a maximum of 0.726 in February, 2009 in Medical Pond, from 0.533 in October, 2009 to 0.668 in January, 2010 in Laldiggi Pond and from 0.544 in February, 2009 to 0.703 in August, 2009 in Chautal Pond.
Correlation between species evenness and some Physico-chemical parameters were also determined. Species evenness showed positive correlation with PO_4-P in two ponds and negative correlation in one of the ponds (Medical Pond: r = 0.507; Laldiggi Pond: r = -0.184; Chautal Pond: r = 0.041).

The highest similarity 91.67% was recorded between April, 2009 – August, 2009 in Medical Pond followed by 90.49 between July, 2009 – September, 2009 in Laldiggi Pond and 90.12 between February, 2009 and April, 2009 in Chautal Pond. The lowest similarity was 75.96 between March, 2009-January, 2010 in Chautal Pond followed by 78.59 between October, 2009 - January, 2010 in Laldiggi Pond and 79.92 in July, 2009 – December, 2009 in Medical Pond. Overall high Similarity index values suggested that most of the species in these ponds were common during the course of study. This has resulted in overlapping of faunal grouping and predictability of community composition.

Canonical correspondence analysis (CCA): The data of benthos and water and sediment quality variables were drawn up in the form of one matrix and were analysed by canonical correspondence analysis (CCA) using PAST program, version (2.10) by Oyvind Hammer and D.A.T Harper, represented in Medical Pond, Laldiggi Pond and Chautal Pond.

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